A RETROSPECTIVE STUDY COMPARING DOUBLE LUMEN TUBE SIZE USED IN THE ADULT INDIAN POPULATION UNDERGOING ELECTIVE SURGERY REQUIRING ONE LUNG VENTILATION AND ISOLATION VERSUS THE DOUBLE LUMEN TUBE SIZE BASED ON BRONCHIAL DIAMETER FROM COMPUTED TOMOGRAPHY OF THE THORAX

Dissertation submitted in partial fulfillment of the requirement of The Tamil Nadu Dr. M.G.R. Medical University for the M.D. Branch X (Anaesthesiology) Examination to be held in April 2013

CERTIFICATE

This is to certify that “A retrospective study comparing double lumen tube size used in the adult Indian population undergoing elective surgery requiring one lung ventilation and isolation versus the double lumen tube size based on bronchial diameter from computed tomography (CT) of the thorax ” is a bonafide work of Dr. Sneha Ann Ancheri in partial fulfillment of the requirements for the M.D. Anaesthesiology examination (Branch X) of The Tamil Nadu Dr. M.G.R Medical University to be held in April 2013.

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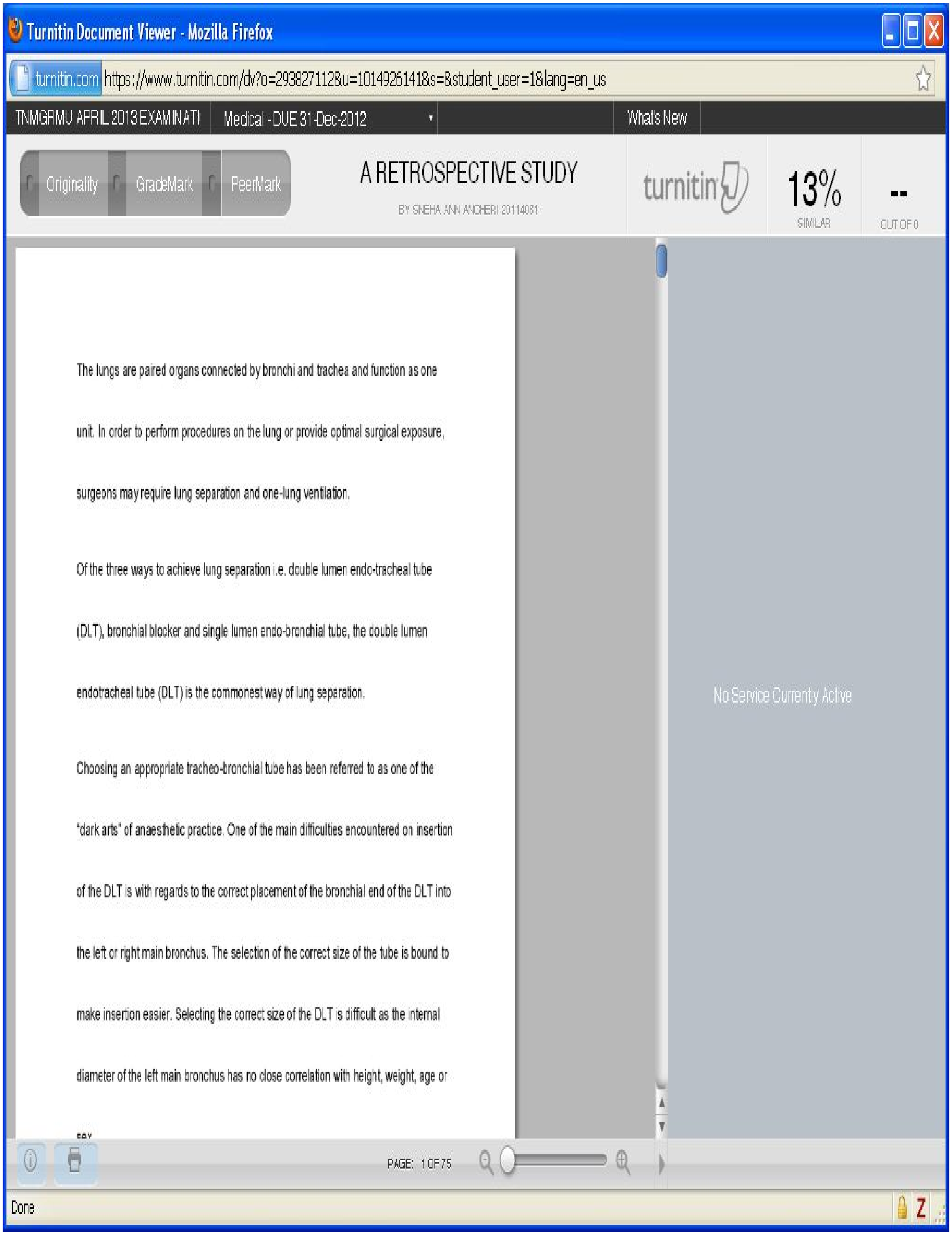
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The lungs are paired organs connected by bronchi and trachea and function as one unit. In order to perform procedures on the lung or provide optimal surgical exposure, surgeons may require lung separation and one-lung ventilation.
Of the three ways to achieve lung separation i.e. double lumen endo-tracheal tube (DLT), bronchial blocker and single lumen endo-bronchial tube, the double lumen endotracheal tube (DLT) is the commonest way of lung separation.
Choosing an appropriate tracheo-bronchial tube has been referred to as one of the "dark arts" of anaesthetic practice. One of the main difficulties encountered on insertion of the DLT is with regards to the correct placement of the bronchial end of the DLT into the left or right main bronchus. The selection of the correct size of the tube is bound to make insertion easier. Selecting the correct size of the DLT is difficult as the internal diameter of the left main bronchus has no close correlation with height, weight, age or
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CONTENTS

INTRODUCTION

The lungs are paired organs connected by bronchi and trachea and function as one unit. In order to perform procedures on the lung or provide optimal surgical exposure, surgeons may require lung separation and one-lung ventilation.

Of the three ways to achieve lung separation i.e. double lumen endo-tracheal tube (DLT), bronchial blocker and single lumen endo-bronchial tube, the double lumen endotracheal tube (DLT) is the commonest way of lung separation.

Choosing an appropriate tracheo-bronchial tube has been referred to as one of the “dark arts” of anaesthetic practice. One of the main difficulties encountered on insertion of the DLT is with regards to the correct placement of the bronchial end of the DLT into the left or right main bronchus. The selection of the correct size of the tube is bound to make insertion easier. Selecting the correct size of the DLT is difficult as the internal diameter of the left main bronchus has no close correlation with height, weight, age or sex.

A simple method of predicting the appropriate size of DLT would be likely to decrease the incidence of laryngeal trauma, reduce the need for repeated intubation attempts and cost associated with the same. Computed

Tomography (CT) of the thorax is an investigation routinely done in patients undergoing elective surgeries requiring one-lung ventilation. The left main bronchus can be easily visualized and the size measured on the CT Thorax. Studies done in Caucasian and Asian populations used CT scans to measure the diameter of the left main-stem bronchus and they found prediction of the size of the double lumen tube based on left main-stem bronchial diameter to be fairly accurate. I have not come across any study done for DLT size determination in the Indian population in published literature.

I would like to compare the size of the left-sided double lumen tube used in the adult Indian population undergoing elective surgery requiring one-lung ventilation and isolation with the size of the double lumen tube based on the left main bronchial diameter from the CT of the thorax. My aim is to assess applicability of recommendations based on a study done in Asian population in Singapore by Chow et al(1999) in the adult Indian population in choosing the correct size of double lumen tube for lung isolation or perhaps come up with recommendations relevant to the Indian population.

AIMS AND OBJECTIVES

AIM:

To assess applicability of internationally derived recommendations using left bronchial diameter from CT scan to determine double lumen tube size in adult Indians undergoing elective surgery requiring one-lung ventilation and isolation.

OBJECTIVES:

1. To determine double lumen tube size based on left main bronchial diameter from computed tomography of the thorax.

2. To determine double lumen tube size used for adequate lung isolation in the Indian population undergoing elective surgery.

3. To compare double lumen tube size that is used for adequate lung isolation in the Indian population undergoing elective thoracic surgery with the calculated double lumen tube size based on left main bronchus diameter from CT scan

LITERATURE REVIEW

HISTORY OF THORACIC ANAESTHESIA:(1)

With the introduction of Inhalational anaesthesia in the 1840s, began the era of modern, safe surgery. With subsequent advances in anaesthetic and surgical techniques and equipment, by 1930, patients could survive most general surgical procedures. This was not true for intra- thoracic surgeries.

Problems with pneumothorax associated with intra-thoracic surgery:(1)

In the 1930s general anaesthesia was administered using ether or chloroform delivered via mask to a spontaneously breathing patient. Although this was an acceptable method in patients with an intact chest in whom respiration was normal, intra-thoracic surgery was a different scenario. With the opening of the chest wall, the operative lung collapsed and the mediastinum shifted to the non-operative side resulting in tachypnea and cyanosis. The paradoxical expansion and contraction of the operative lung in response to exhalation and inhalation due to the transfer of air between the exposed and healthy lung was described as

“Pendulluft”.This gave the surgeon very little time to complete the surgery because the patient would die unless the chest was closed.

A solution to the pneumothorax problem was the only way to perform procedures more difficult than a simple chest wall resection or fluid drainage. In 1904, at a surgical congress in Berlin, two solutions for the pneumothorax problem were brought forward. One solution by Von Mikulicz and Sauerbruch involved placing an animal’s body inside a negative pressure chamber with its head outside. This enabled the animal to breathe unassisted with its chest open. The other solution by Brauer involved placing the patient’s head inside a positive pressure chamber which helped maintain unassisted respiration with an open chest. This was similar to the modern day continuous positive airway pressure (CPAP) devices.

At the time most intra-thoracic procedures were performed for lung infection and although the above devices allowed spontaneous respiration with an open chest, they could not protect the healthy lung from being contaminated by the diseased lung.

Endotracheal tubes and positive pressure ventilation:(1)

In 1895, Tuffier, a French surgeon, made use of a cuffed metal tracheal tube and positive pressure ventilation for intra-thoracic surgeries. Around the same time, Matas in New Orleans proposed the use of controlled ventilation via a tracheal tube for thoracotomy as a solution for the pneumothorax problem. When his proposal became standard practice in thoracotomies more than thirty years later it revolutionized the field of thoracic surgery.

Up until the early 1930s the most commonly used general anaesthetic technique involved the use of ether or chloroform via an open drop mask where the depth of anaesthesia was controlled by the spontaneously breathing patient.

In 1928, Guedel et al used a rubber endotracheal tube with an attached inflatable cuff for controlled respiration with hand bag ventilation. Protection of the lungs from gastric aspiration was provided by the inflated cuff.

Elimination of spontaneous respiration was achieved by physician controlled hyperventilation and deeper levels of anaesthesia resulted in diaphragmatic immobility and apnea.

Although a cuffed endotracheal tube permitting controlled positive pressure ventilation and eliminating the need for spontaneous respiration during chest surgery solved the pneumothorax problem, cross-contamination from the diseased to the healthy lung remained a major problem for patients undergoing thoracic procedures.

Selective one-lung ventilation:(1)

Three years after Guedel et al introduced the cuffed endotracheal tube, Gale et al described a method for selective one-lung ventilation. Using direct laryngoscopy the patient's trachea was intubated with a cuffed rubber endotracheal tube which was further advanced into the healthy lung bronchus. Inflation of the large volume cuff resulted in sealing of the intubated bronchus. The extension of the inflated cuff into the carina obstructed ventilation of the diseased lung. This resulted in the collapse of the obstructed operated lung and ventilation of the healthy lung.

The advantages of selective one-lung ventilation were an immobile surgical field, absence of sudden pneumothorax resulting in shock and protection of the healthy lung from contamination from the diseased lung

In 1920, Magill designed a laryngoscope to assist placement of endotracheal tubes. The introduction of the Macintosh laryngoscope in 1943 greatly helped in endotracheal tube placement and is still in use today.

These advances in anesthetic practice enabled thoracic surgeons to perform previously impossible surgeries.

Bronchial Blockade:(1,2)

In 1935, Archibald introduced a rubber catheter with an inflatable distal balloon into the diseased lung bronchus to control secretions. He used radiographs to confirm the position of the blocker. Inflation of the balloon resulted in blood and secretions being confined to the diseased bronchus and collapse of the lung tissue beyond the inflated balloon. An endotracheal tube inserted by the side of the blocker permitted ventilation of the healthy lung.

In 1936, Magill positioned a similar blocker under direct vision using an endoscope which was passed down the lumen of the blocker tube.

With the withdrawal of the blocker into the trachea following deflation of the balloon, the risk of contamination of the healthy lung from the diseased lung remained.

Rovenstine, in 1936, introduced a double cuffed single-lumen endobronchial tube into the bronchus of the healthy lung. Inflation of the proximal balloon resulted in the ventilation of both lungs. Inflation of both cuffs resulted in the isolation and ventilation of the healthy intubated lung.

Many endobronchial tubes and bronchial blockers have been used in anaesthetic practice since then. The disadvantages with bronchial blockade are that suctioning of secretions, bronchscopic use or re-expansion and recollapse of the diseased lung during surgery are not possible. Possibility of cross contamination with blood, pus or loose tumour material exists upon balloon deflation. Bronchial blockade is used in situations where use of a double lumen tube is difficult i.e. in adults with difficult airways or in small children requiring one-lung isolation and ventilation.

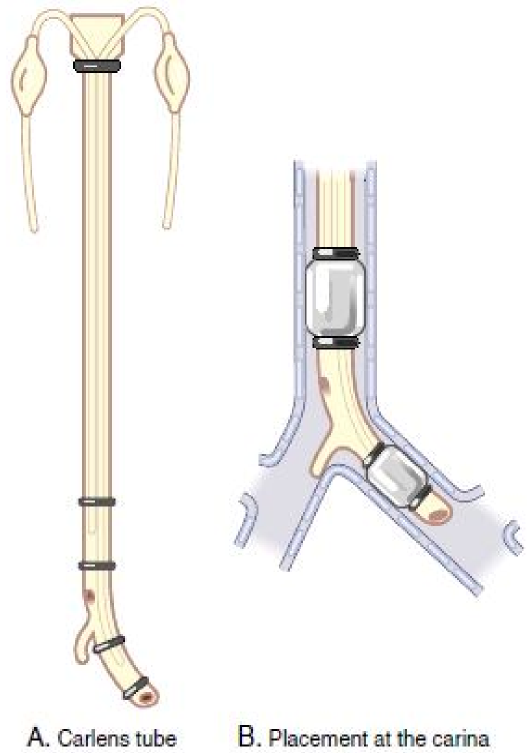
Double-Lumen Tubes:(1,2)

A double-cuffed, double-lumen tube comprises of two tubes of different lengths that are joined to each other. The shorter of the two tubes lies in the trachea while the longer tube lies in the left or the right main bronchus. On inflating the proximal cuff, both lungs can be ventilated. On inflating the distal bronchial cuff, both lungs or either lung can be ventilated by selective clamping of gas flow to the bronchial or tracheal lumen proximally.

Carlens, a clinical physiologist, designed a double lumen tube to intubate the left lung for differential broncho-spirometry in 1949. The Carlens tube was used by Bjork et al in 1950 to achieve one-lung ventilation in thoracic operations. A feature of the Carlens tube was a carinal hook to assist in the blind placement of the tube in the bronchus. Difficulty in passing the carinal hook through the glottis in some patients or airway trauma by the hook was a possibility. Also the narrow lumen of the Carlens tube resulted in resistance to gas flow.(2)

Ten years after the Carlens tube was described, Bryce-Smith designed a similar left sided double-lumen tube without a carinal hook. In 1960, White and Bryce-Smith et al designed a right sided double-lumen tube for right bronchial intubation.

Use of a double-lumen tube in thoracic surgeries permits safe positive pressure one-lung ventilation. Collapse of the diseased lung results in a quiet surgical field, making surgery easier. With the patient in the lateral position for intra-thoracic procedures, use of a double-lumen tube permits lung separation and isolation which protects the dependent healthy lung from aspiration. At any time during surgery, the non-dependent operated lung may be collapsed, re-expanded and re-collapsed safely. Before re-expansion of the operated lung, blood and secretions in the bronchus of the operated lung may be suctioned via the double-lumen tube. This reduces the risk of cross-contamination. Also, a paediatric bronchoscope may be introduced via the double-lumen tube to allow visualization of the bronchus.



(2)

A. Diagram of the Carlen's red rubber tube

B. Placement of the Carlen's tube at the tracheal carina

Clinical use of the double-lumen tube was initially limited by the difficulty in achieving correct placement of the tube and high airway resistance associated with one-lung ventilation.

In 1963, the Robertshaw tube was introduced which dealt with some of the limitations of the older double-lumen tubes. The rubber Robertshaw tube did not have a carinal hook unlike the Carlens and White tubes. The wide lumen facilitated gas flow during one-lung ventilation and the curvature of the tube decreased the risk of kinking.

The disposable, plastic double-lumen tubes in clinical practice today were introduced in the early 1980s.(3) The plastic tubes have a similar design to the reusable rubber Robertshaw tube with certain advantages. The plastic material makes tracheal intubation and bronchial placement both safe and easier. The thin plastic tube wall provides for a larger lumen when compared to a rubber tube of equivalent circumference, resulting in less resistance to gas flow during one-lung ventilation. The larger lumen also makes passage of a suction catheter or fibre-optic bronchoscope easier. The clear plastic allows easy visualization of water-vapour, blood or secretions. The high-volume, low-pressure characteristic of the plastic double-lumen tube cuff, unlike the low-volume, high-pressure cuffs of the rubber tubes, decrease the risk of airway injury.

Later developments include the provision of radiographic markers near the endotracheal and endobronchial cuffs and surrounding the ventilation slot in the right-sided double-lumen tubes. The bright blue endobronchial cuff allows easy visualization during fibreoptic bronchoscopy.(2)

Several manufacturers offer plastic double-lumen tubes today that have a similar design but differ in dimension and cuff characteristics. Tubes are available in sizes 26 to 41 F for left or right lung intubation.

The fibre-optic bronchoscope was first used in the 1980s to assist in double-lumen tube positioning.(4) Although safe blind placement of a double-lumen tube is possible, ease and accuracy of tube positioning is greatly facilitated by fibre-optic bronchoscope use especially for anaesthetists who do not use double-lumen tubes on a regular basis. Also double-lumen tube placement under direct vision decreases the risk of injury or hypoxemia secondary to malposition of the tube.

In conclusion, many of the thoracic surgeries being performed today are possible because of the use of a double lumen tube or bronchial blocker to provide lung separation and a quiet surgical field which results in a reduction in duration of surgery. In procedures involving infection or massive haemorrhage of one lung, lung isolation is mandatory to prevent contamination of other lung. During surgery, control of ventilation to either or both lungs is possible only with a double-lumen tube. A double-lumen tube is a pre-requisite for whole lung lavage for alveolar proteinosis.

Advancement of thoracic surgery as a speciality has closely paralleled advances in anaesthetic practice and equipment.

CHOOSING AN APPROPRIATE DOUBLE –LUMEN TUBE:

Prior to 1995, selection of the correct size of a left double-lumen tube, to provide lung isolation for a patient, had not been dealt with in a scientific manner in literature. (5) Providing lung isolation involved the use of the smallest to the largest double-lumen tube for a patient in clinical practice. Due to a lack of guidelines, selection of size of double lumen tube for an individual was primarily based on personal experience and preference or ill-defined teachings in the standard anaesthesia textbooks.(5,6)

Although for successful placement of double-lumen tubes personal experience is important, improved safety and success would be associated with their use if more objective criteria were used for selection of double-lumen tube size.(7)

Side of double-lumen tube- Left or Right:

Benumof et al defined the margin of safety with respect to double-lumen tube position as “as the length of tracheobronchial tree over which it may be moved or positioned without obstructing a conducting airway”.(8) The authors measured the margin of safety in the positioning of left-sided and right-sided Mallinckrodt, Rusch and Sheridan double-lumen tubes. The following criteria was used to measure the margin of safety: (1) for positioning of the left-sided double-lumen tube (all manufacturers), the margin of safety was defined as the length of the left main-stem bronchus minus the length of the bronchial cuff till the bronchial lumen end; (2) for the positioning of right-sided Mallinckrodt double-lumen tube, the margin of safety was defined as the right main-stem bronchial length minus the length of the bronchial cuff; (3) while for right-sided Rusch tubes, the margin of safety was defines as the length of the slot for right upper lobe ventilation minus the right upper lobe diameter.(8)

Benumof et al concluded that with respect to the margin of safety in positioning double-lumen tubes, left-sided tubes are preferred to right-sided double lumen tubes because of the increased margin of safety with positioning of the left-sided tubes. The authors also recommended that the final position after placement of left or right-sided double-lumen tubes be confirmed by fibreoptic bronchoscopy as the distances involved in determining margin of safety are extremely small.(8)

Thus in most cases a left-sided double-lumen tube is used for one-lung ventilation because the left main-stem bronchial length is about two times the right main-stem bronchial length, increasing the margin of safety in positioning left-sided double-lumen tubes compared to right-sided double-lumen tubes.(9)

Some anaesthesiologists prefer a right-sided double lumen tube for all left sided surgeries.(2) Placement of a right-sided double-lumen tube must be done taking into consideration the location and possible obstruction of the right upper lobe bronchus. The right-sided double-lumen tube usually has a modified bronchial cuff or a separate ventilation slot to allow ventilation of the right upper lobe.

The indications for the use of a right-sided double-lumen tube are:(2)

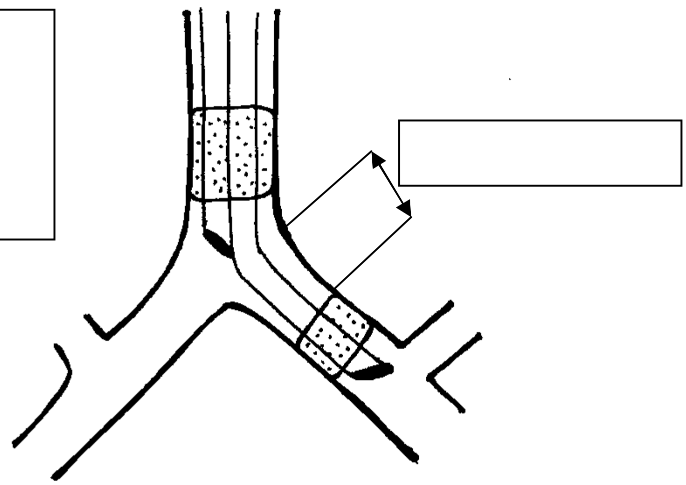
(1) Distorted Anatomy of the left main-stem bronchus

- Intraluminal or external compression of bronchus by tumour
- Descending thoracic aortic aneurysm

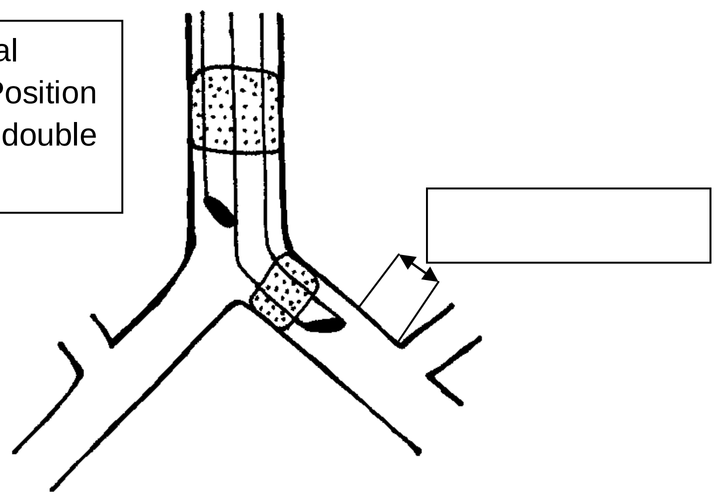
(2) Left main-stem bronchus included in the site of surgery

- Left lung transplantation
- Left-sided tracheo-bronchial disruption
- Left-sided sleeve resection
- Left-sided pneumonectomy: may be done using a left-sided double-lumen tube or bronchial blocker which must be withdrawn prior to stapling the left main-stem bronchus.

Most Distal Acceptable Position for left sided double lumen tube



Most Proximal Acceptable Position for left-sided double lumen tube



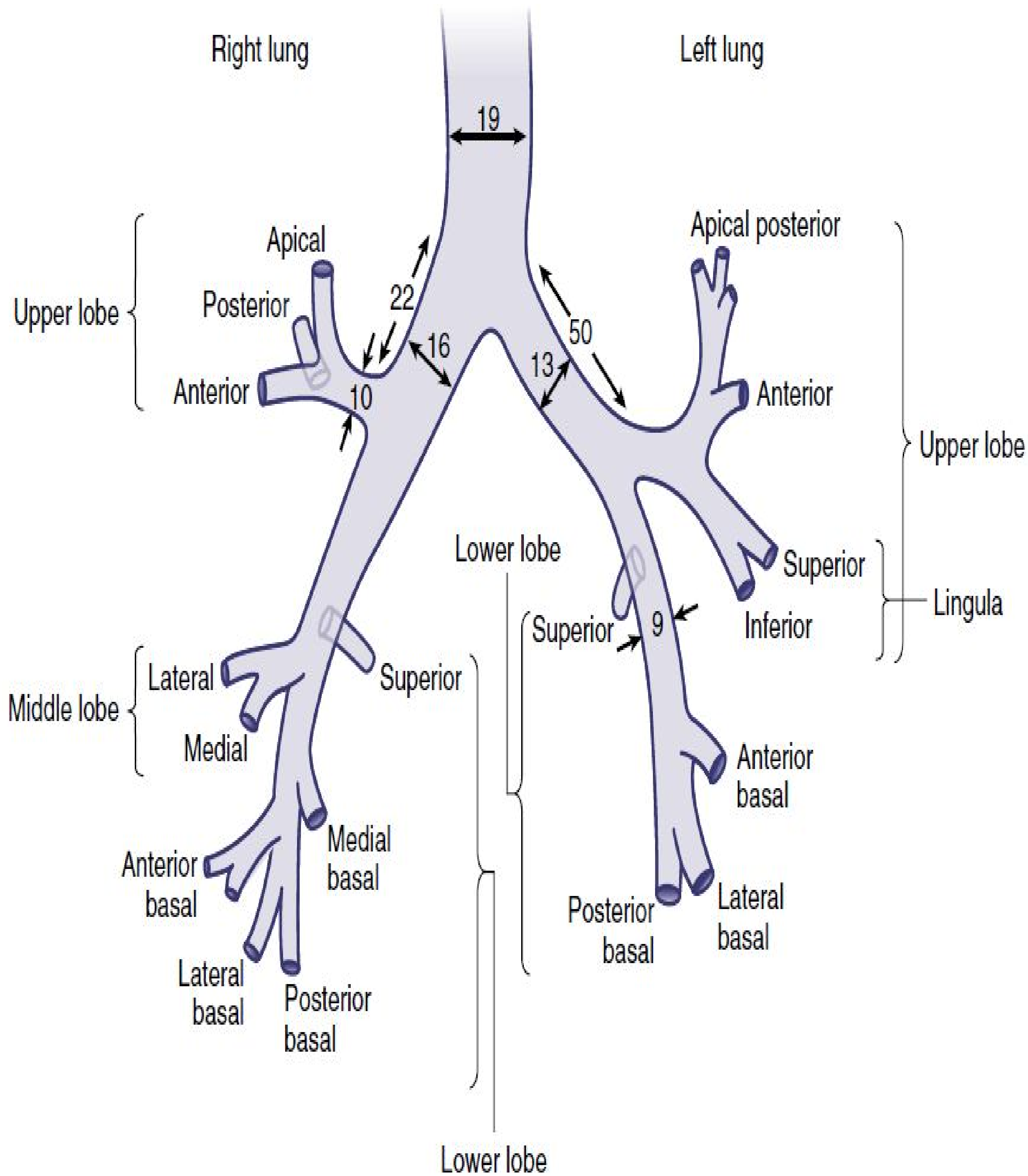


Diagram of the tracheobronchial tree. Lengths and diameters in mm.(2)

Appropriate size of double-lumen tube:

The choice of size of double-lumen tube for an individual patient is an important one. A wrong sized tube can cause airway trauma or inadequate lung isolation and oxygenation during one-lung ventilation.(10)

An appropriately sized double-lumen tube would meet two criteria: (a) in the presence of a deflated bronchial cuff, an air leak would be detectable, meaning that the tube is not too big for the bronchus and (b) inflation of a volume less than the bronchial cuff's resting volume is sufficient to maintain an airtight seal. Inflation of a greater volume than the cuff's resting volume may cause the cuff to lose its low-pressure character.(7,11)

Hannallah et al defined resting volume of the low-pressure, high-volume cuff as the volume at which the cuff is inflated to its natural shape. In other words, the resting volume is the maximum volume at which the low pressure characteristic of the cuff is maintained. The resting volume of the cuff is an important determinant of cuff compliance which is related to the risk of bronchial damage. If the bronchial cuff has to be inflated more than its resting volume to achieve an adequate seal in a properly placed double-lumen tube, the size of the double-lumen tube is wrong for that individual. The authors studied the pressure-volume relationship of the bronchial cuffs of 35, 37, 39 and 41 Fr sizes of Mallinckrodt, Sheridan, Rusch and Portex left sided double-lumen tubes. The bronchial-cuff resting volume for each cuff was determined as the cuff volume beyond which an additional volume of 0.5 ml contributed to a rise in cuff pressure of more than 10 mm of Hg.(12)

The authors found that the smaller sized Mallinckrodt and Sheridan double-lumen tubes had larger bronchial cuff resting volumes and lower bronchial cuff pressure than the larger-sized Mallinckrodt and Sheridan tubes. They concluded that this was probably because the different sizes of Mallinckrodt and Sheridan double-lumen tubes were fitted with a bronchial cuff of the same size. The smaller sized tube thus occupied a smaller area within the cuff compared to the larger sized tube. As a result, in Mallinckrodt and Sheridan tubes, the bronchial cuff resting volume decreases with an increase in tube size while the cuff pressure changes proportionately with the tube size.(12)

In contrast, the smaller-sized Rusch and Portex double-lumen tubes had smaller bronchial cuff resting volumes and higher bronchial cuff pressure compared to the larger-sized Rusch and Portex double-lumen tube. In these two brands larger bronchial cuffs were fitted in the larger double-lumen tubes as compared to the smaller double-lumen tubes which is why the larger tubes have larger cuff resting volume and lower bronchial cuff pressure than the smaller tubes.(12)

In our institution we use Mallinckrodt left-sided double lumen tubes of sizes 32, 35, 37, 39 and 41F for one-lung ventilation and isolation in adults. According to Hannallah et al, the resting volume (mean+/- standard deviation) of the bronchial cuffs of various sizes of Mallinckrodt tubes is as follows:(12)

DLT size (F)	35	37	39	41
Resting volume (ml)	3.7±0.2	2.5±0.0	2.0±0.0	2.0±0.0

The mean bronchial cuff pressure in Mallinckrodt double-lumen tubes at 3ml volume was found to be as follows: 35F < 37F < 39F and 41F double-lumen tubes.(12)

Another recommendation is that the transmitted pressure by the bronchial cuff on the bronchial wall must be less than 30 mm of Hg, beyond which mucosal capillary perfusion decreases, thus increasing the risk of ischaemic bronchial damage.(13)

Roscoe et al studied intra-cuff pressures and transmitted pressures of 35, 37, 39 and 41 sizes of left-sided double-lumen tube and three types of endo-bronchial blockers using a silicon tubing of 12.8 mm internal diameter as an in-vitro model of the adult main stem bronchus. The authors used four strain-guage microchip sensors, which were placed on the anterior, posterior and lateral surfaces of the cuff, to measure the pressures exerted by the cuff. The cuff was inflated with 1 ml increments and the transmitted pressure sensed by the four transducers noted. The highest transmitted pressure sensed by the four transducers and the mean pressure of all four devices were recorded. Intra-cuff pressure was simultaneously measured.(13)

Roscoe et al found that with inflation of the double-lumen tube cuff with 2 to 6 ml, the transmitted pressures were less than 30 mm of Hg which is recommended to prevent mucosal ischemic damage. This may be due to the cuff's internal elastic recoil which balances the high intra-cuff pressure. The authors concluded that with cuff inflation volumes in clinical use, only about 10 to 20 % of the intra-cuff pressure is transmitted to the bronchial wall, which is within the safe limit. One drawback was that the authors used a silicon model to mimic the adult main bronchus which may not be a perfect substitute because of its slightly greater distensibility compared to the adult bronchus. (13)

Hannallah et al, after studying cuff pressure and volume, was also of the opinion that cuff pressure was not an indicator of the pressure transmitted to the bronchial wall by the cuff. The intra-cuff pressure in low-pressure and less compliant cuffs is mostly needed to maintain cuff inflation and the pressure transmitted to the bronchial mucosa is therefore much less.(12)

According to Hannallah et al, the optimal left double-lumen tube size for a particular individual is defined as the largest tube that can be placed in the left main bronchus with a small detectable air leak when the bronchial cuff is deflated. The importance of the air leak with the deflated bronchial cuff is the insurance that the tube is not wedged too tightly in the bronchus which could result in bronchial injury especially with empirical inflation of the bronchial cuff. (6) A pre-determined amount of air must not be used to inflate the bronchial cuff to avoid bronchial injury. Instead the minimal amount of air necessary to provide lung isolation, which is different for each patient, must be used for bronchial cuff inflation.(5) The advantages of using the largest possible tube are less airway resistance to gas flow, easier passage of the suction catheter or fibre-optic bronchoscope via the wider lumen and the small cuff volume required for effective bronchial seal.

Two requirements with regard to selection of the optimal sized double-lumen tube are that it must pass atraumatically through the glottis and the bronchial lumen must pass into the intended bronchus.(14)

Seymour et al conducted a cadaveric study to establish a relationship between the adult cricoid ring diameter and the tracheobronchial tree. The authors concluded that in both sexes, the mean cricoid diameter was the same as the left main-stem bronchial diameter.(15)

Therefore the optimal double-lumen tube size for an individual may be determined if we had knowledge of the diameter of the bronchial end of the double-lumen tube and the individual's left main-stem bronchial diameter. (6)

The diameter of the bronchial end of the appropriate double-lumen tube must be 1 to 2 mm less than the intubated bronchial diameter to easily accommodate the deflated bronchial cuff.(6)

Disadvantages of an inappropriately sized double-lumen tube:

Too small a tube could result in a failure to provide lung isolation in terms of failure of collapse of the operated lung or contamination of the healthy dependent lung(14). In order to provide lung isolation with a smaller tube, excessive endo-bronchial cuff volumes and pressures would have to be used which could result in cuff herniation into the trachea or ischaemic bronchial injury.(5,10) Over-inflation of the low-pressure bronchial cuff of the double-lumen tube beyond its resting volume will change it to a high-pressure cuff which has the potential to cause bronchial mucosal injury.(12) Also, further advancement of very small tubes into the bronchus is a possibility which would result in hypoxemia during one-lung ventilation due to the obstruction of the upper lobe orifice by the bronchial cuff.(10) Advancement of a fibre-optic bronchoscope or suction catheter is more difficult through the smaller lumen. An increase in gas flow resistance during one-lung ventilation is associated with the use of smaller tubes. With the use of a smaller double-lumen tube a greater amount of intrinsic positive end-expiratory pressure is generated during one-lung ventilation.(10)

On the other hand, a double-lumen tube that is too large could result in tracheal or bronchial rupture(5)

Use of patient characteristics for double-lumen tube size:

Jay B. Brodsky et al found that age, height and weight were not reliable criteria to predict left main-stem bronchial diameter.(14)

Other investigators also concluded that patient characteristics like age, sex, height, weight and body surface area were not reliable predictors of the individual's left main-stem bronchial diameter.(7,9) P. Slinger was of the opinion that with regard to monitoring in anaesthesia, when a clinically important variable cannot be reliably predicted, it must be measured.(5) He felt that an understanding of the anatomic basis of the difficulty in providing safe one-lung anaesthesia would shed some light on the "somewhat dark art" of providing one-lung ventilation.(5)

Hannallah et al examined 100 preoperative postero-anterior and lateral chest x-rays in patients, from the age of 18 to 89 years, to see if the left main-stem bronchial diameter could be predicted accurately from the patient's age, sex, weight or height. The authors chose chest x-rays of patients without any known lung or cardiac pathology, thoracic cage deformity or thoracic surgery in the past. Chest x-rays with a clear left main-stem bronchial diameter were to be selected but the bronchial outline was clearly defined in only half the chest x-rays, so more than 200 chest x-rays had to be examined for 100 bronchial measurements. Hannallah et al concluded that reliable prediction of the left main-stem bronchial diameter could not be made from the patient's age, height or weight.(6)

In our institution, the double-lumen tube size is commonly determined based on the height and sex of the patient as recommended by in the 7th edition of Miller's Anaesthesia. (2)

Height in males	DLT size (F)
>170 cm (67 inches)	41
</=170 cm	39
If <160 cm (63 inches)	To consider 37 F

Height in females	DLT size (F)
>160 cm (63 inches)	37
</=160 cm	35
<152 cm (60 inches)	Examine bronchial diameter on CT and consider 32F DLT

Use of chest X-ray for double-lumen tube size:

After examining 100 pre-operative postero-anterior and lateral chest x-rays in patients, Hannallah et al suggested that the bronchial diameter may be directly measured from pre-op chest x-rays, where the bronchial outline was clearly identified in 50% of chest x-rays. To compensate for the magnification of intra-thoracic structures in postero-anterior chest x-ray films, the measured bronchial diameter must be reduced by 8 to 10 %. Hannallal et al suggested that if chest Computed Tomography(CT) scans were available, they may be used to directly measure the left bronchial diameter for which no compensation for magnification was required.(6) The success rate of identifying the bronchial outline in a chest x-ray increases to about 69% with the use of filmless digital chest x-rays. This is due to the better visualization of the air bronchogram in the digital image where the adjustment of the contrast and penetration of the image is possible.(9)

In contrast to the left bronchial diameter that is clearly visible in the posterior-anterior view in chest x-rays 50% of the time, the tracheal diameter was clearly visible in all chest x-rays examined by Jay B. Brodsky et al.(6,14) The authors measured the tracheal width at the clavicular level in posterior-anterior chest x-rays in 70 patients scheduled to undergo an intra-thoracic surgery. The double-lumen tube to achieve lung isolation for the intra-thoracic procedure was selected for the individual based on the tracheal diameter as measured from the pre-operative chest x-ray.(14)

The trachea and bronchus were successfully intubated in all 70 patients by the selected double-lumen tube. Three of the seventy patients were intubated with larger tubes than recommended by the guidelines. Jay B. Brodsky et al experienced some difficulty in advancing the tube past the vocal cords in 10 (14.3%) patients and in 19 (27.1%) patients there was mild resistance while passing the tube into the bronchus from the trachea. In 18 (25.7%) patients the wrong bronchus was intubated in the first attempt. The left bronchus was intubated after deflating both cuffs and maneouvering the tube into the left bronchus after withdrawing it proximal to the carina. The selected double-lumen tube functioned efficiently in all 70 patients in terms of an absence of hypoxic episodes and achieving successful lung collapse. (14)

The authors established a significant correlation between the tracheal and bronchial widths for an individual as measured from the chest x-rays. According to Jay B. Brodsky et al the left bronchial diameter could be determined by multiplying the measured tracheal width by 0.68. Selection of double-lumen tube for an individual could thus reliably be made by estimation of the bronchial width from the measured tracheal width. (4, 5)

Brodsky and Lemmens examined 321 chest x-rays of patients scheduled for intra-thoracic procedures in which both tracheal and left bronchial widths could be measured. Analysis of age, sex, height and weight for prediction of the left main-stem bronchial width was done. The authors found a weak but significant correlation between height and left bronchial width in both men and women. The authors concluded that direct measurement of the left main-stem bronchial diameter would be the best for selection of double-lumen tube size but if direct measurement was not possible, tracheal width was the best predictor of left main-stem bronchial width in both men and women.(7)

Chow et al selected sixty-six Asian adults scheduled for surgery requiring the placement of a double-lumen tube for one-lung ventilation and isolation. The authors excluded patients who had a history of tracheostomy or any disease associated with tracheal or bronchial narrowing. Chow et al aimed at assessing the applicability of the tracheal diameter as suggested by Brodsky et al to select the appropriate double-lumen tube for the smaller sized Asian patient.(11, 12)

Chow et al measured the tracheal width at the inter-clavicular level on a pre-operative chest x-ray and a BronchoCath double-lumen tube (Mallinckrodt, St. Louis, MO) was chosen based on the suggestions of Brodsky et al i.e. for tracheal width of <15mm a 35 F tube, for tracheal width >15mm and <16mm a 37F tube, for tracheal width of >16mm and <18mm a 39 F tube and for a tracheal width of >18mm a 41 F tube was selected. The positioning of the double-lumen tube was confirmed by auscultation. Fibre-optic bronchoscopy was performed with which the bronchial cuff was visualized just beyond the carina with no herniation into the opposite bronchus and the left upper and lower bronchial lumens were not blocked by the tube's bronchial end. The double-lumen tube was considered appropriate if (a) a small air leak was detected with the deflated cuff, (b) if the volume required for cuff inflation to obtain an air-tight seal was less than the recommended resting volume and the cuff pressure was less than 20 cm of water. The tube was considered too big if an air leak with the cuff deflated was absent. The tube was considered too small if the volume used for bronchial cuff inflation exceeded the resting cuff volume or the bronchial cuff pressure exceeded 20 cm of water.(16)

Chow et al found that with the above recommendations they often chose an oversized double-lumen tube, especially for their female patients. The positive predictive value for the male patients was

77.3% and the positive predictive value for the female patients was 45.5%. Chow et al proposed that the difference in result between their study and that of Brodsky et al was probably due to (a) the inclusion of resting cuff volume as a criterion for appropriate double-lumen tube selection and (b) a difference in patient characteristics where the Asian patients, especially the women, tended to be of smaller built and shorter stature. The authors concluded that reliable selection of double-lumen tube size was not possible using tracheal width as measured from a chest x-ray, especially for the Asian female patient. As clinical decisions were based on a difference of 1 to 2 mm, accurate measurement of the left bronchial width would probably be a better predictor of double-lumen tube size.(16)

Use of thoracic computed tomographic scan for DLT size:

Hannallah et al prospectively examined chest computed tomographic (CT) scans done as a pre-operative investigation in 20 patients scheduled for elective intra-thoracic procedures as the bronchial anatomy is more accurately measured in chest computed tomographic scans than chest x-rays.(7)

A computerized tomographic scan is a means of obtaining a cross-sectional image of the body in slices of thickness 7 to 10 mm. The advantages of a chest computerized tomographic scan over a chest x-ray are as follows:(7)

(a) The bronchi are better identified on a computerized tomographic scan as distortion from overlying soft tissue is absent

(b) On the computerized tomography the bronchial outline is well defined unlike in chest x-rays where the bronchial outline is identified in only 50 % of the chest x-rays

(c) Identification of anatomical abnormality of the bronchi such as wall thickening or narrowing of the bronchial lumen by a lesion is possible with computerized tomography

(d) The visualization of the lungs or other intra-thoracic structures can be improved by altering the density of the chest computerized tomographic scans.

Hannallah et al measured the left bronchial diameter from the computed tomographic scan to guide selection of the size of the double-lumen to be used to achieve one-lung isolation and ventilation for the individual. Measurement of the left main-stem bronchial diameter was made on the first CT scan slice just beyond the carinal level where the two bronchi were visualized as singular structures. The bronchus looks artificially elongated on the horizontal slice of the CT scan as it takes an oblique course through the plane of the CT scan slice. Thus, the bronchial diameter was measured, using fine calipers, perpendicular to the long axis of the bronchus.(7)

For an individual patient, Hannallah et al used a left Mallinckrodt DLT whose bronchial end diameter was 1 to 2 mm smaller than the individuals' measured left main-stem bronchial diameter to accommodate for the deflated bronchial cuff. Fibre-optic bronchoscopy was performed to confirm proper positioning of the double-lumen tube in terms of visualization of the blue bronchial cuff inside the left bronchial lumen just beyond the carina. Inflation of the bronchial cuff was performed while checking for an air leak. The air leak was checked for by application of 25 cm of water peak airway pressure to the bronchial side with the tracheal side of the double-lumen tube connected to a 1 cm underwater seal. The selected double-lumen tube size was deemed appropriate for the individual if (a) with the bronchial cuff deflated, an air leak was detected suggesting that the tube was not too big for the left bronchus and (b) a maximum of 2 ml was inflated into the bronchial cuff to achieve an airtight seal. Volumes of more than 2 ml might cause the bronchial cuff to lose its low-pressure characteristic, increasing the risk of bronchial mucosal injury.(7)

Hannallah et al encountered no difficulty in double-lumen tube positioning and complete collapse of the operated lung in all 20 patients. The selected double-lumen tube was deemed appropriate in 17 of the 20 patients as both criteria were fulfilled. The 3 patients who failed to meet the criterion of the presence of an air leak with the bronchial cuff deflated were women, in whom the left main-stem bronchi measured 8.0, 9.5 and 10 mm and the smallest adult left double-lumen tube, 35 F, sealed the bronchi without bronchial cuff inflation. The authors were of the opinion that it is for this subset of patients whose left main-stem bronchus measures less than 10 mm that knowledge of the bronchial diameter for double-lumen tube selection is of greatest importance in order to avoid both undue force while introducing the tube and empirical inflation of the bronchial cuff without checking for a leak. Hannallah et al suggested a possible need for a smaller adult double-lumen tube than 35F for use in adults with bronchi less than 10 mm. Another safer alternative than forcing a double-lumen tube into a bronchus smaller than the tube's bronchial end to achieve one-lung isolation and ventilation would be to use a bronchial blocker.(7)

Hannallah et al concluded that the bronchial diameter measured from the computerized tomographic scan of the chest may be used as an objective guide for double-lumen tube size for an individual. Measurement of the left main-stem bronchus on the computerized tomographic scan is not perfect. This is inevitable due to a difference in bronchial diameter during inhalation and exhalation and the left bronchus is not exactly round in shape because a part of the posterior wall of the bronchus is membranous. Enlarging the computerized tomographic scan slice and the use of fine calipers for measurement would help make the measurements more exact.(7)

Hannallah et al suggested that more studies were required to assess the usefulness of using the left bronchial diameter measured from a chest CT scan to select an appropriate double-lumen tube for an individual as opposed to other approaches like anaesthetist's experience, patient's sex or height and bronchial diameter derived from chest x-ray.(7)

Chow et al selected fifty Asian adults, with a pre-operative computerized tomographic scan of the thorax, requiring the placement of a double-lumen tube for elective intra-thoracic procedures. The left main-stem bronchus was measured, using electronic calipers of a spiral scanner by a radiology colleague, 7 to 10 mm below the slice showing the carina and where both bronchi were visualized as singular structures. Measurements were made in a direction perpendicular to the most parallel portion of the bronchus, similar to Hannallah et at.(7) For left main-stem bronchial diameters of <10 mm, 10 mm, 11 mm, 12 mm and >12 mm, the sizes of double-lumen tubes selected were 32F, 35F, 37F, 39F and 41F respectively.(17)

All the double-lumen tubes were placed by anaesthetists with a minimum of five years' experience in using a double-lumen tube.

Confirmation of double-lumen tube position was done using fibre-optic bronchoscopy with which the bronchial cuff was visualized just beyond the carina without obstruction of the left upper lobe bronchus. A positive pressure technique, as used by Hannallah et al(7), was used to confirm lung isolation, by which pressure of 30 cm of water was applied to the bronchial lumen and a leak via the tracheal lumen was checked for by connecting it to a 1cm underwater seal. The bronchial cuff was inflated till no leak was detected from the underwater seal. The selected double-lumen tube was considered to be of appropriate size if the volume required to achieve an air-tight seal by bronchial cuff inflation was more than 0 but less than the resting volume of the cuff. On the other hand, absence of a leak with the bronchial cuff deflated meant that the tube was over-sized for the patient. The tube was deemed under-sized if inflation of the bronchial cuff to obtain an air-tight seal required more than the cuff's resting volume.(17)

In the study all patients were successfully intubated with the pre-determined double-lumen tube. 12 out of 50 (24%) patients were found to receive an over-sized tube while none received an under-sized tube. The positive predictive value for the male patients was 84.4% while the positive predictive value for the female patients was 61.1%. The authors concluded that by using the left main-stem bronchial width as measured from a chest tomographic scan, prediction of double-lumen tube size for an individual was fairly accurate, especially when it came to the smaller sized double-lumen tubes.

Russell and Strong stated that the various manufacturers of double-lumen tubes do not indicate the external diameter of the bronchial segment of the tube on the tube or in the accompanying leaflet. The authors measured the bronchial cuff lengths and diameters of 171 left double-lumen tubes ranging in size from 28 to 41 F from four manufacturers using calipers. The authors found that apart from wide variation between manufacturers, there was wide variation between tubes of the same French gauge from the same manufacturer. The variation in bronchial segment between tubes of the same French gauge does not seem secondary to shrinkage due to aging or washing as the observed variation in tube dimension was not consistent. The authors concluded that the current French gauge markings for left-sided double-lumen tubes are of limited value in determining the appropriate size for a patient. The authors recommended that more accurate dimensions of double-lumen tubes are required to improve safety and success associated with double-lumen tube selection.(18)

PATIENTS AND METHODS

SETTINGS:

The study was done in the Operation theatre in the Main Theatre Complex of Christian Medical College and Hospital, Vellore, Tamil Nadu, India. Christian Medical College is a tertiary care centre in South India catering to patients from North India and Bangladesh in addition to South India.

The Cardio-Thoracic Department performs about 250 to 300 thoracic procedures a year, about half of which require lung isolation using a double-lumen tube. The Gastro-Intestinal Surgical Unit performs about one to two esophagectomies per month requiring one lung isolation and ventilation using a double-lumen tube.

In our institution, there is no definite protocol to choose the double-lumen tube size for an individual. It is most commonly based on personal experience or preference. Various criteria may be used including sex and height as mentioned in standard anaesthesia textbooks or radiological measurements of the tracheal or bronchial diameters from the chest Xray or computed tomography scan of the thorax. Computed Tomographic scans of the thorax are routinely done in almost all patients scheduled to undergo a thoracotomy in our institution.

INCLUSION CRITERIA:

1. Age more than 17 years and less than 80 years

2. Elective surgery requiring one lung ventilation and isolation with a left-sided double-lumen tube.

3. Computed Tomographic scan of thorax done as part of routine preoperative work-up.

EXCLUSION CRITERIA:

1. Age more less than 17 years and more than 80 years

2. Patients requiring a right-sided double-lumen tube to achieve one lung isolation and ventilation

3. Patients with a documented difficult airway

4. Mediastinal mass causing distortion of airways

The study recruited patients who met the inclusion criteria from November 2011 to November 2012. The protocol received approval from the Institutional Review Board of Christian Medical College, Vellore and was funded by the fluid research fund of the Christian Medical College, Vellore.

Data was collected retrospectively either from the anaesthetist who used a double-lumen tube to achieve one-lung isolation and ventilation in the selected patient or from the anaesthesia record of the selected patient obtained from the Medical Records Department of Christian Medical College, Vellore.

Name of patient/ Hospital Number	
Age and Sex	
Height and weight	
Size and Side of Initial DLT	
Number of attempts	
Size and Side of final DLT	
Complications:* 1.Failure to advance the DLT 2.Trauma 3. Inadequate Isolation 4.Wrong side	
Amount of air for cuff inflation (bronchial and tracheal cuff)*	
Cuff pressure(bronchial and tracheal)*	
Confirmation with FOB: yes/no	
Tracheal Diameter from CT Thorax	
Left Main Bronchial diameter from CT	
Size of DLT calculated based on CT measurements	

*If mentioned

A single Consultant Radiologist examined the chest X-ray and thoracic computed tomographic scan of the selected patient and noted the tracheal diameter from the chest X-ray and tracheal diameter and both main-stem bronchial diameters from the computed tomography scan.

In our institution, the Radiology Department has a 6 slice and a 16 slice multi-detector computed tomographic scan machine. Most of the scans that were analysed were done on either of the two machines. Some patients had outside scans which were stored as digital images in the picture archiving and communication system (PACS). Outside scans were analysed for our study only if the scale was mentioned.

A computed tomographic scan of the thorax is done after contrast is administered to the patient. The patient is made to lie supine and asked to hold his breath in inspiration while the thorax is scanned. 5 mm thick (slice thickness) contiguous sections are taken and sent to the picture archiving and communication system (PACS) for image storage, reporting and future reference.

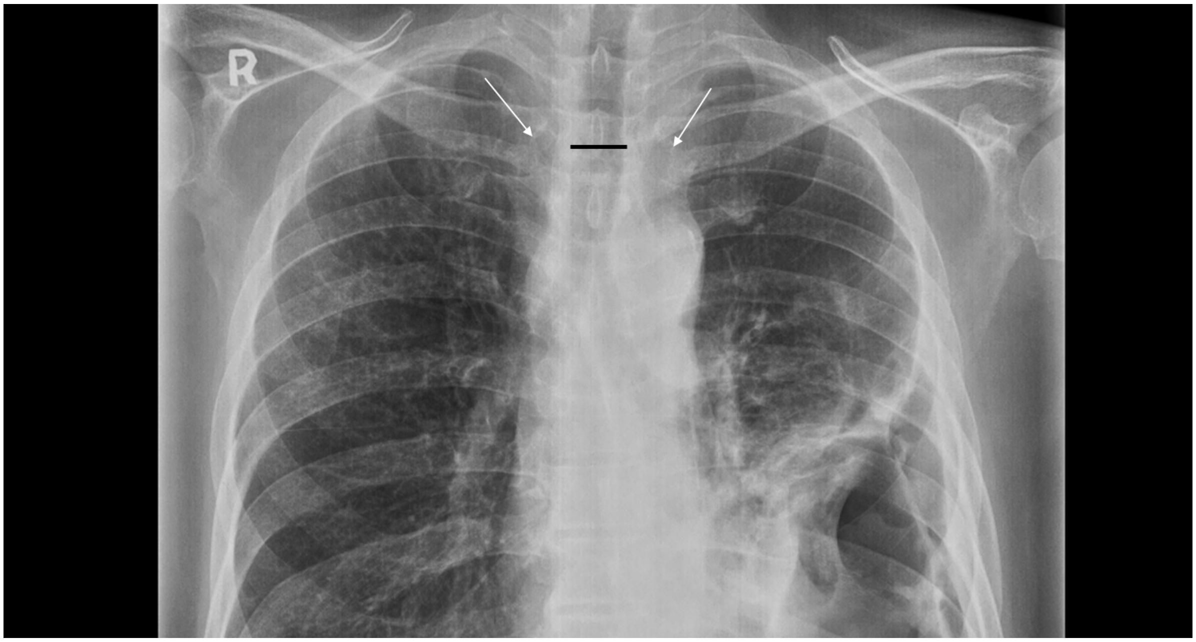
Measurements of the thoracic diameter from chest X-ray, the thoracic and main-stem bronchial diameters from computed tomographic scans, for all the study patients, were done by a single Consultant Radiologist. All measurements were done on the PACS monitor using electronic calipers available on the PACS system. PACS also enables visualization and measurement of digital images on computers in the Operation Theatre.

Tracheal and bronchial measurements were done in the following manner:

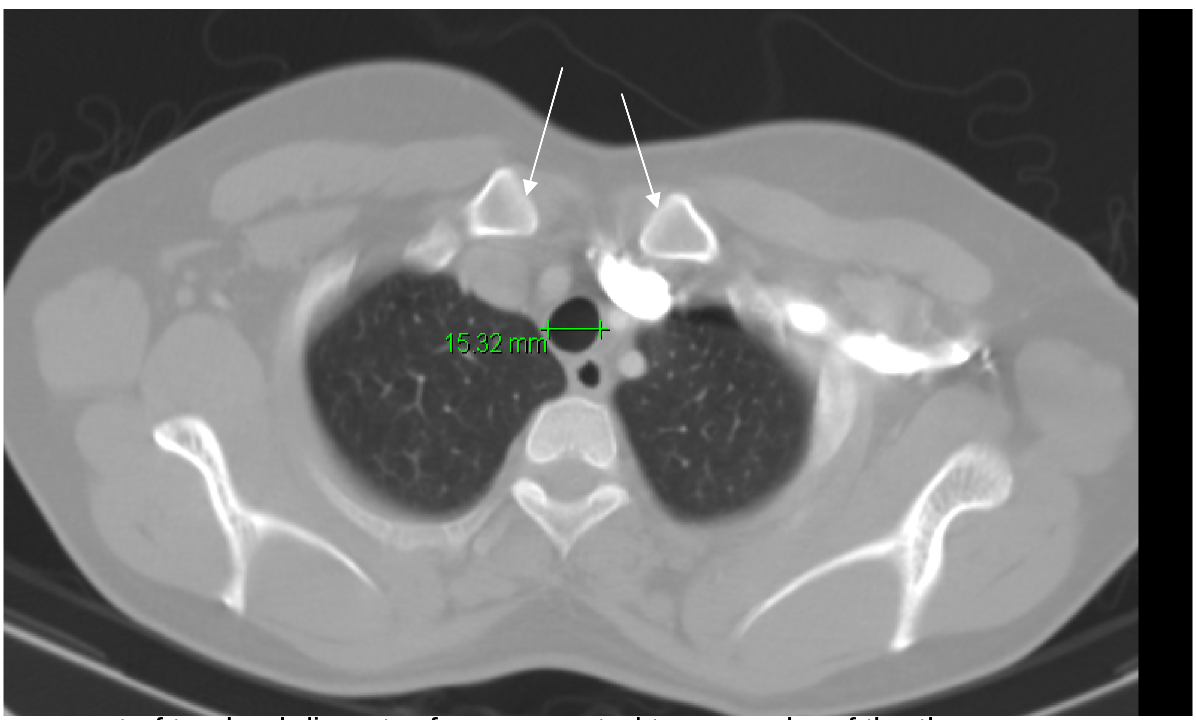
(1) On the chest radiograph, tracheal diameter was taken as the maximum transverse diameter measured at the level of the medial end of the clavicles.

(2) On the computed tomographic scan of the thorax, tracheal diameter was taken as the maximum transverse diameter measured at the level of the medial end of the clavicles. Bronchial diameter was measured just below the level of the carina, where the right and left bronchi were seen as singular structures. Measurement of the bronchial diameter was usually in the antero-posterior dimension, perpendicular to the long axis of the bronchus.

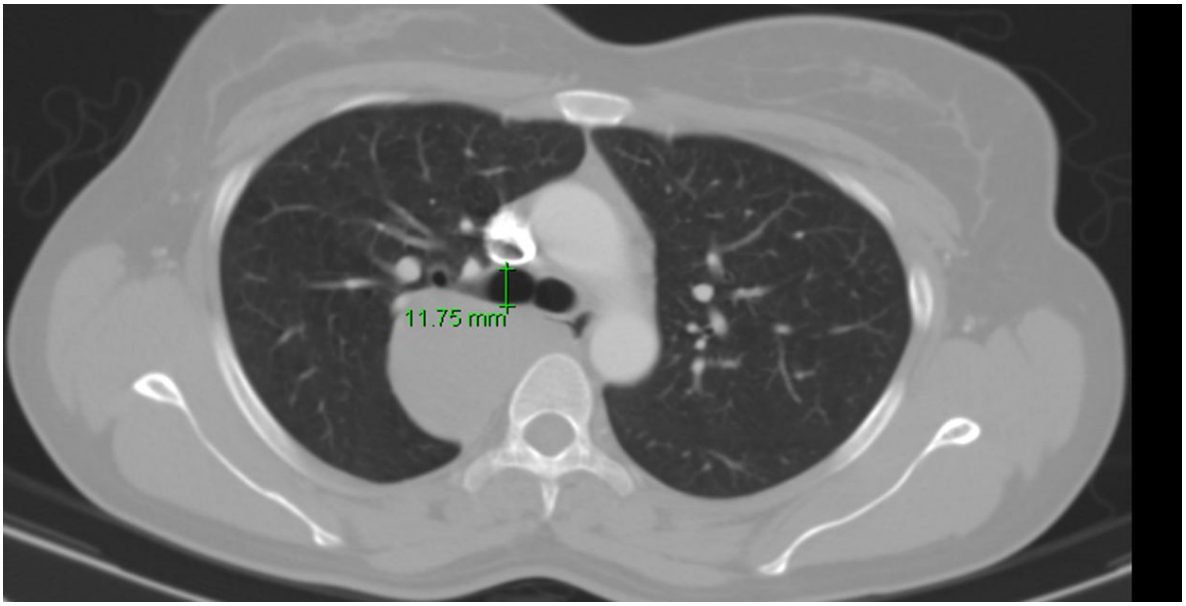
The computed tomographic images of the thorax were sufficiently enlarged and were viewed in the lung window settings prior to measurement of the tracheal and bronchial diameters.



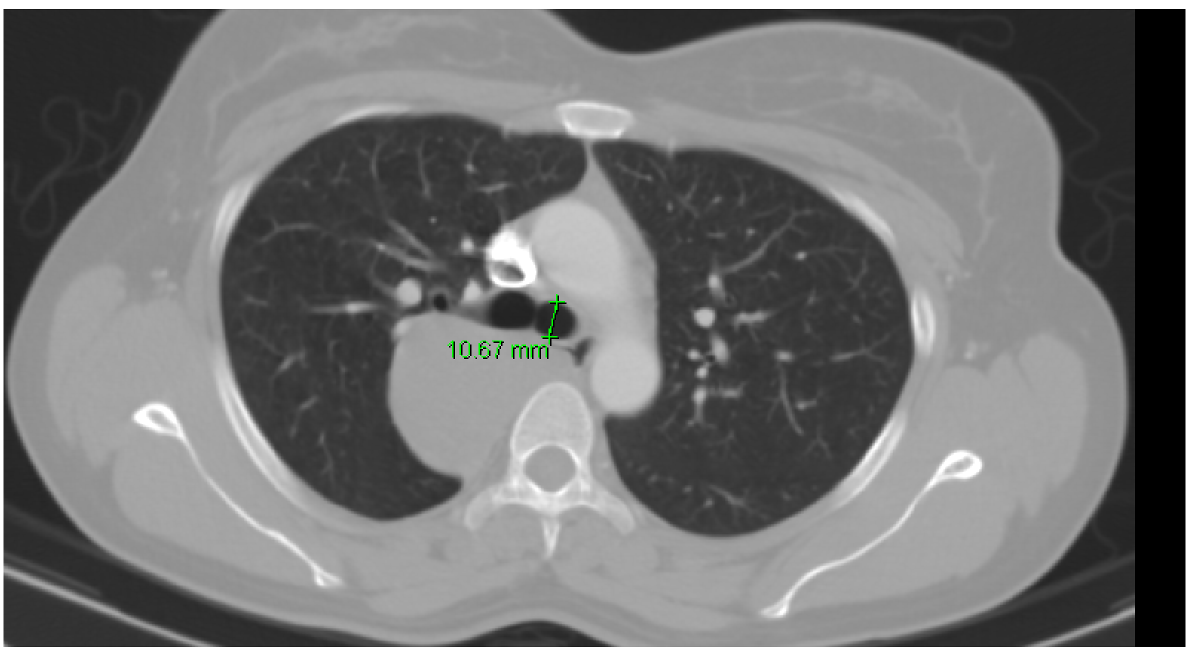
Measurement of tracheal diameter from chest X-ray: Transverse diameter of trachea (black line) at the level of the clavicles (white arrows)



Measurement of tracheal diameter from computed tomography of the thorax: Transverse or coronal diameter of trachea (green line) on CT at the level of the clavicles (white arrows)



Measurement of right bronchial diameter from computed tomography of the thorax: Diameter of right main bronchus, just beyond carina (green line)



Measurement of left main-stem bronchial diameter from computed tomography of the thorax: Diameter of left main bronchus, just beyond carina (green line)

The double-lumen tube size based on tracheal diameter from Chest X-ray was chosen using the following criteria based on the study done by Chow et al in the Singapore population: (16)

Tracheal Diameter (mm)	<15	15-16	16-18	>18
DLT (F)	35	37	39	41

The double-lumen tube size based on bronchial diameter from computed tomographic scan was chosen using the following criteria:

Bronchial Diameter (mm)	<10	10-11	11-12	12-13	>13
DLT(F)	32	35	37	39	41

The double-lumen tube size based on height and sex was chosen using the following criteria according to Miller’s Anaesthesia 7th edition: (2)

Height in males	DLT size (F)
>170 cm (67 inches)	41
</=170 cm	39
If <160 cm (63 inches)	To consider 37 F

Height in females	DLT size (F)
>160 cm (63 inches)	37
</=160 cm	35
<152 cm (60 inches)	Examine bronchial diameter on the CT scan and consider 32F DLT

SAMPLE SIZE:

In the study done by Chow et al in the Singaporean population using bronchial diameter to predict double-lumen tube size, the positive predictive value was found to be 84.4% for males and 61.1% for females.

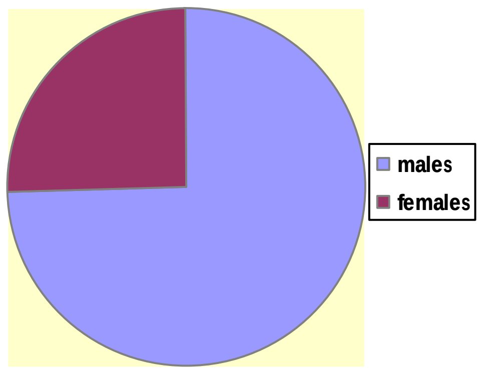
Sample size was calculated using the formula 4pq/d2, where p denotes a positive predictive value of 75%, q=100-p, d is the precision of 10 %, with alpha of 5%. Based on this calculation, the study aimed at recruiting 75 patients who underwent elective surgery requiring one lung isolation and ventilation using a double-lumen tube. The study was stopped at 55 patients in order to meet the deadline for submission of thesis.

STATISTICAL METHODS:

Statistical analysis was done using SAS (Statistical Analysis System) Software. All categorical variables were described using mean and standard deviation. All continuous variables were described using frequency and percentages.

RESULTS

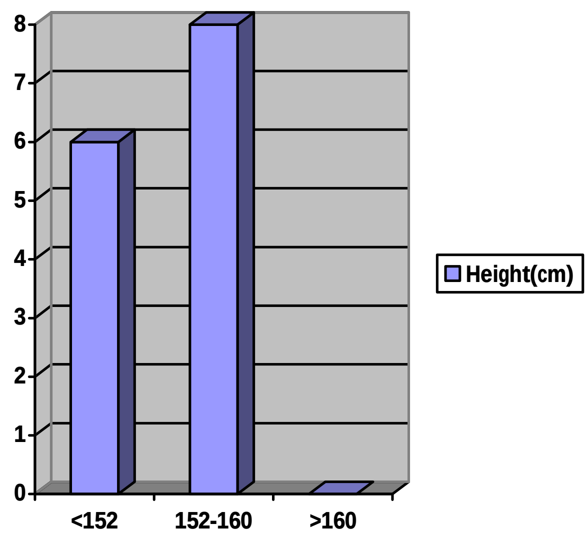
55 patients requiring one-lung isolation and ventilation for elective surgery using a double-lumen tube were recruited in the study.



Demographic Data of the male and female study patients:

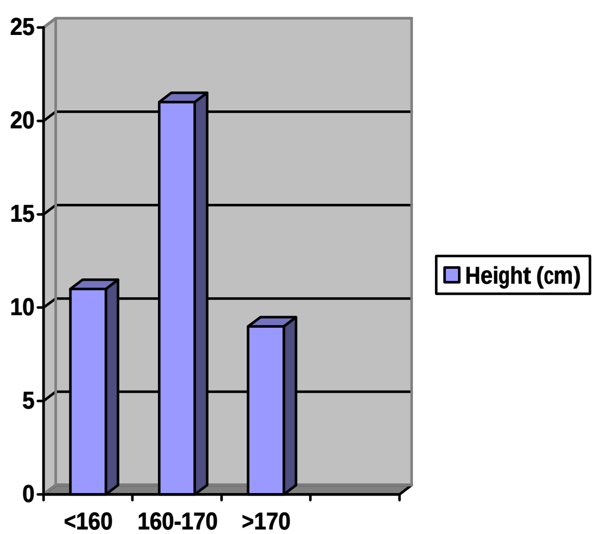
	Males	Females
Age (yrs.)	40.9 ± 13.9	41.2 ± 9.4
Height (cm)	164 ± 7.5	152 ± 4.5
Weight (kg)	58±11.5	54.6±10

Distribution of height in the 14 female study patients:



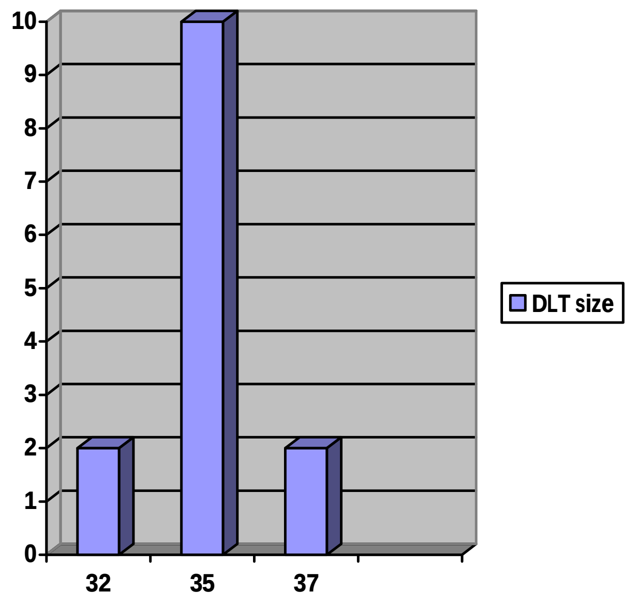
Of the 14 females, ten females were intubated with a 35 F DLT, two females with a 32 F DLT and two females with a 37 F DLT.

Distribution of height among 41 male study patients:



Of the 41 male study patients, 11 males were less than 160 cm in height, 21 males were 160 to 170 cm tall and 9 males were more than 170 cm tall.

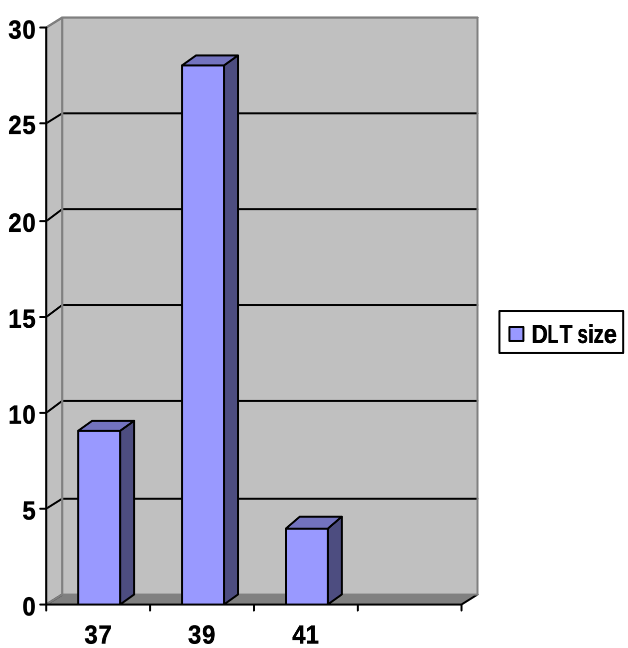
<u>Size of double-lumen tube used in 14 females:</u>



Of the 14 females, two females were intubated with a 32 F DLT, two females with a 37 F DLT and ten females with a 35 F DLT.

Four females required more than one attempt at intubation, three of whom received an oversized DLT in the first attempt.

<u>Size of double-lumen tube used in 41 males:</u>



Of the 41 males, nine males were intubated with a 37 F DLT, twenty-eight males with a 39 F DLT and four males with a 41 F DLT.

Six males required more than one attempt at intubation, of whom one male received an oversized DLT and one male received an undersized DLT in the first attempt.

(1) <u>Comparing the DLT size chosen based on the tracheal diameter of the patient (DLT tracheal) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in males:</u>

	DLT used			
DLT tracheal	37	39	41	Total
32	1	0	0	1
37	1	5	0	6
39	2	6	1	9
41	5	16	3	24
Total	9	27	4	40

Of the 41 males, the tracheal diameter of one male could not be determined from chest radiograph. Comparison of the DLT used to achieve one lung isolation and ventilation in the remaining 40 males with the DLT size based on tracheal diameter measured from chest radiograph revealed a correlation in 10 out of 40 males i.e. in 25% of the males.

7 males were intubated with a DLT larger than the DLT predicted from tracheal diameter, while 23 males received a DLT smaller than the DLT based on tracheal diameter.

(2) <u>Comparing the DLT size chosen based on the tracheal diameter of the patient (DLT tracheal) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in females:</u>

	DLT used			
DLT tracheal	32	35	37	Total
32	0	1	0	1
35	0	2	0	2
37	1	2	1	4
39	0	4	0	4
41	1	1	1	3
Total	2	10	2	14

Comparison of the DLT size used to achieve one lung isolation and ventilation in the 14 females with the DLT size calculated from tracheal diameter measured on a chest radiograph revealed a correlation in 3 out of 14 females (21%).

One female was intubated with a DLT larger than the DLT predicted from tracheal diameter. The remaining 10 females received a DLT smaller in size as compared with the DLT size predicted from the tracheal diameter.

(3) Comparing the DLT size chosen based on the bronchial diameter of the patient (DLT bronchial) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in males:

	DLT used			
DLT bronchial	37	39	41	Total
32	1	2	0	3
35	0	3	1	4
37	5	7	0	12
39	0	8	0	8
41	3	8	3	14
Total	9	28	4	41

Comparison of the DLT size used to achieve one-lung isolation and ventilation in 41 males with the DLT size predicted from the bronchial diameter measured from chest computed tomography scans revealed a correlation in 16 out of 41 males (39%).

14 males were intubated with a DLT bigger than that predicted from the bronchial diameter while 11 males received a DLT smaller than that predicted from the bronchial diameter.

(4) Comparing the DLT size chosen based on the bronchial diameter of the patient (DLT bronchial) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in females:

	DLT used			
DLT bronchial	32	35	37	Total
32	2	4	0	6
35	0	5	1	6
37	0	1	0	1
39	0	0	1	1
Total	2	10	2	14

Comparison of the DLT size used to achieve one-lung isolation and ventilation in 14 females with the DLT size predicted from the bronchial diameter measured from thoracic computed tomographic scans revealed a correlation in 7 out of 14 females (50%).

5 females were intubated by a DLT larger than that predicted from bronchial diameter while 2 females received a DLT smaller than the DLT predicted from bronchial diameter.

(5) <u>Comparing the DLT size chosen based on the height and sex of the patient (DLT height) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in males:</u>

	DLT used			
DLT height	37	39	41	Total
37	4	2	0	6
39	5	21	0	26
41	0	5	4	9
Total	9	28	4	41

Comparison of the DLT size used to achieve one-lung isolation and ventilation in 41 males with the DLT size based on height and sex of the patient revealed correlation in 29 out of 41 patients (70%).

2 males were intubated with a DLT larger than that predicted based on height and sex while 10 patients received a DLT smaller in size compared to the DLT based on height and sex.

Weighted Kappa for DLT height by DLT used in males: 0.4917,

ASE: 0.1219 (not significant)

(6) Comparing the DLT size chosen based on the height and sex of the patient (DLT height) versus the DLT size used to achieve one-lung isolation in the patient (DLT used) in females:

	DLT used			
DLT height	32	35	37	Total
32	1	1	0	2
35	1	9	2	12
Total	2	10	2	14

Comparison of the DLT size used to achieve one-lung isolation and ventilation in 14 females with the DLT size based on sex and height revealed a correlation in 10 out of 14 females (71%).

3 females were intubated with a larger DLT than the DLT size based on sex and height while one female received a smaller DLT than the DLT size based on sex and height.

(7) Comparing the DLT size chosen based on height and sex (DLT height) versus the DLT size chosen based on the bronchial diameter of the patient (DLT bronchial) in males: 36% correlation

	DLT bronchial					
DLT height	32	35	37	39	41	Total
37	1	1	4	0	0	6
39	1	2	6	7	10	26
41	1	1	2	1	4	9
Total	3	4	12	8	14	41

(8) Comparing the DLT size chosen based on height (DLT height) versus the DLT size chosen based on the bronchial diameter of the patient (DLT bronchial) in females: 57% correlation

	DLT bronchial				
DLT height	32	35	37	39	Total
32	2	0	0	0	2
35	4	6	1	1	12
Total	6	6	1	1	14

(9) Complications with double-lumen tube insertion:

(a) Failure to advance the double-lumen tube

Failure to advance	Sex		
	Male	Female	Total
No	39	12	51 (92.73%)
Yes	2	2	4 (7.27%)
Total	41 (74.55%)	14 (25.45%)	55 (100%)

By Fisher's exact test, p value is 0.2655 (not significant)

(b) Inadequate Isolation

Inadequate Isolation	Sex		
	Male	Female	Total
No	41	14	55
Yes	0	0	0
Total	41	14	55

Isolation was adequate in all 55 study patients.

(c) Trauma caused during double lumen placement

Trauma	Sex		
	Male	Female	Total
No	41	13	54 (98.18%)
Yes	0	1	1 (1.82%)
Total	41 (74.55)	14 (25.45%)	55 (100%)

By Fisher's exact test, p value is 0.2545 (not significant)

(d) Double-lumen tube introduced into the wrong side

Wrong side	Sex		
	Male	Female	Total
No	38	12	50 (90.91%)
Yes	3	2	5 (9.09%)
Total	41 (74.55)	14 (25.45%)	55 (100%)

By Fisher's exact test, p value is 0.5924 (not significant)

(10) Demographic Data

DLT	32Fr	35Fr	37Fr	39Fr	41Fr
Ht.*	150 ±3.5	150± 5.2	158±6.7	163±6.5	176±3.1
Wt.*	52±14.1	54±10.2	53±10.9	59±12	65±7.2
Age	47.5±5	40.9±14	35±17	42.6±23	43.3±20
Sex	2 F	10F	2F+9M	28M	4M
LBD	7.9±0.3	9.82±2	11.74±3	12±3.5	13.68±3

*Ht: Height, Wt.: Weight, F: female, M: male, LBD: left bronchial diameter

The mean height of study patients who received a double-lumen tube of 32F and 35F is similar (150 ± 3.5 and 150 ± 5.2 respectively). Study patients who received 37 and 39 F DLT had a height less than 170 cm (mean height of 158 ± 6.7 and 163 ± 6.5 respectively). All patients taller than 170 cm received a 41 F DLT (mean height 176 ± 3.1).

The mean left-main bronchial diameter is observed to increase as the size of the double-lumen tube used to achieve one-lung isolation and ventilation increased from 32 F to 41 F. All study patients with a left main-bronchial diameter ≤ 10 mm received a 32 F or 35 F double-lumen tube for successful one-lung ventilation and isolation.

(11) <u>Height in relation to the size of double-lumen tube used and left main bronchial diameter in females:</u>

Height(cm)	<152	152-160	>160
LMBD(mm)*	10.17±1.6	9.45±1.26	
Number of DLT size(F)* used	one 32 four 35 one 37	one 32 six 35 one 37	

LMBD: left main bronchial diameter, DLT: double-lumen tube, F: French

None of the 14 study females were taller than 160 cm.

According to the sex and height criteria for selection of double-lumen size, if a female is less than 152 cm in height the bronchial diameter must be visualized and a 32 F double-lumen tube considered. In the 6 females who were less than 152 cm in height the mean left bronchial diameter was 10.17±1.6mm. If the left-main bronchial diameter was less than 10 mm, a 32 F DLT may be used. For a left-main bronchial diameter from 10 to 11 mm, a 35 F DLT might be used. One of the females less than 152cm tall received a 37 F DLT without any complication; her left main bronchial diameter was 12.1 mm.

The mean left-main bronchial diameter for the 8 females with height ranging from 152 to 160 cm was 9.45 ±1.26mm. By the sex and height criteria a 35

F DLT would be appropriate. 6 females received a 35 F DLT, in one of whom a 37 F DLT was initially attempted. One female received a 32 F DLT after an initial attempt at intubation with a 35 F DLT was made; her left main-stem bronchial diameter was 8.2 mm. One female received a 37 F DLT in the first attempt without any complication, her left main-stem bronchial diameter was 10.5 mm.

(12) Height in relation to the size of double-lumen tube used and left main bronchial diameter in males:

Height(cm)	<160	160-170	>170
LMBD(mm)*	11.7±1.7	12.3±1.6	12.5±2.2
Number of DLT size(F)*	four 37 seven 39	five 37 sixteen 39	five 39 four 41

*LMBD: left main bronchial diameter, DLT: double-lumen tube, F: French

According to the height criterion in males, if less than 160 cm tall, a 37 F DLT may be considered. Mean left-main bronchial diameter in men <160 mm was 11.7±1.7mm, where 11 to 12 mm bronchial diameter would receive a 37 F DLT and 12-13 mm would receive a 39 F DLT. None of the males < 160 cm received an over-sized DLT.

DISCUSSION

Even decades after the establishment of one-lung ventilation and isolation, selection of the size of double lumen tube for an individual is primarily based on personal experience and preference or formulas based on height and sex of the patient. Conventional teaching also recommends that the largest double-lumen tube that can be placed must be used. The use of double-lumen tubes would be associated with improved safety and success if more objective criteria were used for selection of double-lumen tube size. In our institution selection of double lumen tube size is often based on the Consultant's experience or the height and sex criteria as described in the 7th edition of Miller's Anaesthesia Textbook. Over the years studies have been done to assess the usefulness of more objective criteria for double lumen tube size selection like tracheal diameter from chest radiograph or bronchial diameter from computed tomography of the thorax.

Computed Tomography (CT) of the thorax is an investigation routinely done in patients undergoing elective surgeries requiring one-lung ventilation in which the left main bronchus can be easily visualized and the diameter measured. Studies done in Caucasian and Asian populations used CT scans to measure the diameter of the left main-stem bronchus and they found prediction of the size of the double lumen tube based on left main-stem bronchial diameter to be fairly accurate. Due to a lack of studies in literature with respect to DLT size determination in the Indian population, we proposed to compare the DLT size used to achieve one-lung ventilation and isolation in our patient population with the DLT size based on bronchial diameter measured from computed tomography of the thorax.

Forty-one male and fourteen female patients of Indian origin were included in the study. Information regarding the double-lumen tube size used to achieve one-lung ventilation and isolation was collected retrospectively.

Successful lung isolation after the first attempt at intubation using a double lumen tube in our study patients was 81.8% (45/55). But the success rate in the females was 71% (10/14) while it was 85.4% (36/41) in the males.Most female study patients were intubated with a 35 F DLT (71%) and most male study patients were intubated with a 39 F DLT (68%). Our results were comparable to the figures reported in literature.

We agree with Hannallah that the measurements on computed tomography scans require training and may not be accurate when performed by amateurs. Since our study was retrospective, we involved a Radiology colleague in our study to make the desired radiological measurements. Measurements of the trachea from chest radiograph and of the bronchi from computed tomography of the thorax were done by a single Consultant Radiologist similar to measurements done in previous studies by Hannallah et al and Chow et al. As the bronchial diameter is probably mildly oblique due to the way the bronchi course with respect to the slice sections on the computed tomography scan, measurement of the bronchial diameter was made perpendicular to its long axis.

The difficulties encountered by the Radiologist were:

- Many a time the chest radiographs may be rotated which distorts the tracheal measurement.
- Occasionally the borders of the trachea were not well delineated on the chest radiograph secondary to rotation and overlap of tissues.
- As the trachea and bronchi are not exactly round in cross section, measuring only the transverse and antero-posterior dimensions may not be accurate.
- Measurements made from the outside computed tomography films were difficult as electronic calipers could not be used. Outside films without a scale were excluded from the study.
- The computed tomography of the thorax must be done with the patient's breath held in inspiration. The bronchial diameter decreases in expiration. Since the decision regarding double-lumen tube size is based on the difference of a few millimeters in bronchial diameter, we excluded the patients whose computed tomography revealed obviously expiratory slices. In addition to this, the diameter of the bronchial end of the different sizes of double-lumen tubes is reported to vary by 0.4 mm. In a few patients, the bronchial diameter predicted a double-lumen tube size one or two smaller than the double-lumen tube which was used to achieve one-lung ventilation

and isolation. One reason could be that the computed tomography was not taken with the patient's breath held in inspiration, resulting in a smaller left main-stem bronchial diameter on imaging.

Correlation between the DLT sizes used to achieve one-lung isolation and ventilation in the study patients and the DLT sizes based on tracheal diameter, left-main bronchial diameter and height and sex of the patient was analyzed. Although no statistically significant correlation was found, the highest correlation for the DLT used was with the DLT size based on sex and height (70 % in males and 71% in females). Our results suggest that the DLT size determined from sex and height, based on recommendations in the 7th edition of Miller's Anaesthesia, is a useful criterion in Indian population.

Comparison of our study with the study done by Chow et al(16) reveals that the height of the Indian female is similar to the South-East Asian female. None of the 14 females measured more than 160 cm in height.

No statistically significant correlation between height and left bronchial diameter in both males and females was noted, similar to previous studies.(7)

Based on measurements from computed tomography, the average left main-stem bronchial diameter of our female patients was 9.76±1.39mm and the average left main-stem bronchial diameter of our male patients was 12.20±1.77mm.

In our study the average tracheal diameter is 16.98±2.15mm and the average bronchial diameter is 11.58±1.99 mm. The left main-stem bronchial diameter was

0.68 times the tracheal diameter, similar to previous observations by Brodsky et al.(14)

Analysis of the complications associated with DLT insertion (i.e. failure to advance the DLT, inadequate isolation, trauma and wrong side) with relation to sex was not statistically significant.

It was observed that 3 out of 14 females received an over-sized double-lumen tube while only 1 out of 41 males received an over-sized double-lumen tube requiring intubation with a smaller sized double-lumen tube. Complications secondary to an over-sized double-lumen tube (failure to advance the tube and trauma) was 21% in females and 2.4% in males.

Three of the fourteen female patients were intubated with an over-sized double-lumen tube and required a smaller double-lumen tube for one-lung ventilation and isolation.

- Two of the female study patients required a 32 F double-lumen tube which was placed after an initial attempt at intubation using a 35 F double-lumen tube.

- One of them was 153 cm tall with a left main-stem bronchial diameter of 8.2 mm. The double-lumen tube size based on the bronchial diameter was 32 F. Failure to advance the 35 F double-lumen tube and multiple attempts at intubation may have been avoided if bronchial diameter had been measured prior to double-lumen tube placement.

- The other female patient was 148 cm tall with a bronchial diameter of 7.6mm. According to the sex and height criteria for double-lumen tube size selection in Miller's Anaesthesia textbook, in females with height less than 152 cm, the bronchial diameter must be assessed and a 32 F double-lumen tube may be considered. In this patient less than 152 cm, evaluation of the bronchial diameter would have prompted the use of a 32 F double-lumen tube which may have avoided the failure to advance the 35 F double-lumen tube as well as the associated trauma and multiple attempts at intubation.
- A third female patient who was 160 cm tall was intubated with a 35 F double-lumen tube after an initial attempt at intubation with a 37 F double-lumen tube. The 37 F double-lumen tube was found to be too big. Her left main-stem bronchial diameter was 9.1 mm based on which a 32F double-lumen tube would have been predicted. Based on the sex and height criteria, a patient with a height of 152 to 160 cm may be intubated with a 35F double-lumen tube.

As our numbers are small we are not able to derive any statistically significant results from these observations. In light of the above observations, it may be recommended that the bronchial diameter in addition to height be used for selection of double-lumen tube size in short females in order to improve the initial success rate and minimize the complications.

Hanallah et al stated that in patients with bronchial diameter ≤ 10mm, knowledge of the bronchial diameter was important prior to choosing the size of double-lumen tube. He recommended that in patients with bronchial diameter ≤ 10 mm, a double-lumen tube smaller than 35 F should be used as a 35 F double-lumen tube would wedge tightly in the bronchus. In our study, all study patients with a left main-bronchial diameter ≤ 10 mm received a 32 F or 35 F double-lumen tube for successful one-lung ventilation and isolation.

Previous studies done by Chow et al were prospective and the results using tracheal and bronchial diameter to determine double-lumen tube size were described in terms of positive predictive value. (16, 17) As our study was retrospective, our results could not be assessed in terms of positive predictive value due to a lack of a gold standard.

CONCLUSIONS

Successful lung isolation after the first attempt at intubation using a double lumen tube was 81.8% (45/55). But the success rate in the females was 71% (10/14) while it was 85.4% (36/41) in the males. In male patients, double-lumen tube selection based on experience and the height criteria seems to be accurate. We observed that in the smaller female patients using more than one criterion (height and left main bronchial diameter) will improve success rates.

Selection of double lumen tube size based on the height and sex of the individual (2) correlated best with the double-lumen tube size used to achieve good lung isolation in our study patients.

The double-lumen tube size based on left main bronchial diameter did not statistically correlate with the double-lumen tube size used to achieve one-lung ventilation and isolation in our study patients. We observed that if the bronchial diameter in our shorter females was measured prior to double-lumen tube size selection, complications like repeated attempts at intubation with an over-sized tube, failure to advance the over-sized double-lumen tube and associated trauma may be avoided.

Although the complication rate associated with our current criteria for DLT size selection is low, the number of attempts at intubation may be reduced by using more than one criterion for DLT size selection.

There is a learning curve associated with DLT size selection so anaesthetists in training must be encouraged to make a well-informed choice taking into account the patient characteristics as well as radiological measurements.

In conclusion, using the sex and height criteria for prediction of double-lumen tube size in the Indian population seems reliable. In patients with a height <160 cm, using additional criteria like left main-stem bronchial diameter to select the double-lumen tube size will improve the success rate and reduce complications associated with double-lumen tube use especially in occasional thoracic anaesthetists.

LIMITATIONS

Although the calculated sample size was 75 patients, the study was stopped at 55 patients in order to meet the deadline for submission of thesis. This may be the reason for statistically insignificant results.

As data was collected retrospectively, certain values like amount of air used to inflate the tracheal and bronchial cuff, cuff pressure and the reason for more than one attempt at intubation were not always mentioned.

Computed tomography scan measurements are accurate to the millimeter. We observed that timing of imaging is important. The measured left main-stem bronchial diameter may be less if imaging is not done during inspiration.

Mallinckrodt double-lumen tubes were used to achieve one-lung ventilation and isolation in the 55 study patients. Our observations may not be applicable to double-lumen tubes from other manufacturers.

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DATA ENTRY SHEET

id	hno	hno1	sex	age	ht	wt	sur
1	129290	F	1	32	166	52	RIGHT THORACOTOMY
2	200611	F	1	53	156	48	RIGHT WINDOW PROCEDURE
3	208670	F	1	35	165	68	LEFT 7TH RIB EXCISION
4	200959	F	1	47	171	55	RIGHT THORACOTOMY
5	71892	F	1	51	170	74	RIGHT UPPER LOBE BULLECTOMY
6	210748	F	1	47	158	54	LEFT LOWER LOBECTOMY
7	213284	F	2	45	160	71	RIGHT LOWER LOBECTOMY
8	192261	F	2	47	151	69	LEFT THORACOTOMY
9	197355	F	2	38	145	44	RIGHT THORACOTOMY
10	155640	F	1	22	175	75	LEFT THORACOTOMY AND MASS EXCI
11	147507	F	2	54	148	52	WHOLE LUNG LAVAGE
12	741384	D	1	20	171	65	RIGHT PNEUMONECTOMY
13	195239	F	1	36	170	77	RIGHT PNEUMONECTOMY
14	207866	F	1	35	164	37	BULLECTOMY
15	148734	F	1	55	172	75	MCKEOWN'S ESOPHAGECTOMY
16	150738	F	1	54	163	62	MCKEOWN'S ESOPHAGECTOMY
17	221380	F	1	17	158	40	RIGHT DECORTICATION
18	182481	F	1	17	173	68	RIGHT DECORTICATION
19	169906	O	1	65	157	47	RIGHT DECORTICATION
20	156590	F	1	44	165	54	THORACOTOMY
21	237994	F	1	62	163	56	RIGHT THORACOTOMY
22	235104	F	2	53	152	51	RIGHT THORACOTOMY
23	125208	F	2	40	151	69	RIGHT THORACOTOMY
24	244024	F	1	19	165	68	RT THORACOTOMY
25	250466	F	2	43	148	62	RIGHT THORACOTOMY
26	249680	F	1	65	163	83	RIGHT THORACOTOMY
27	225380	F	1	56	154	48	RIGHT THORACOTOMY
28	932281	D	1	55	160	55	THORACOTOMY
29	175217	F	1	31	150	35	LEFT THORACOTOMY
30	263164	F	2	42	153	60	RIGHT THORACOTOMY
31	232007	F	1	37	169	64	MCKEWON'S OESOPHAGECTOMY
32	289386	F	1	43	173	63	RIGHT THORACOTOMY
33	286150	F	1	39	155	63	RIGHT THORACOTOMY
34	230308	F	1	38	170	59	RIGHT UPPER LOBECTOMY
35	223094	F	1	30	160	61	RIGHT THORACOTOMY AND LOBECTOM
36	291344	F	2	24	155	39	RT THORACOTOMY AND BULLECTOMY

37	238709	F	1	41	180	75	RIGHT UPPER LOBECTOMY
38	51905	F	2	45	158	56	RIGHT LOWER LOBECTOMY
39	295513	F	2	38	145	48	LEFT THORACOTOMY
40	302019	F	1	63	178	64	LEFT THORACOTOMY
41	297942	F	1	41	160	48	RIGHT UPPER LOBECTOY
42	279114	F	2	30	156	52	THORACOSCOPIC EXCISION
43	284787	F	1	60	166	70	RIGHT THORACOTOMY
44	310049	F	1	18	160	45	RIGHT THORACOTOMY
45	289742	F	1	31	166	64	ANT MEDIASTINAL MASS EXCISION
46	245344	F	1	41	150	44	RIGHT WINDOW PROCEDURE
47	542712	D	1	40	161	57	RIGHT THORACOTOMY
48	319409	F	1	45	152	44	RIGHT THORACOTOMY
49	225771	F	2	26	154	50	RIGHT MIDDLE LOBECTOMY
50	323018	F	1	30	154	46	RIGHT THORACOTOMY
51	282490	F	1	44	162	56	RIGHT THORACOTOMY
52	48358	F	2	52	153	42	LEFT LOWER LOBECTOMY
53	86036	F	1	33	168	56	LEFT LOWER LOBECTOMY
54	213244	F	1	59	158	61	RIGHT LOWER LOBECTOMY
55	332144	F	1	26	175	58	RIGHT THORACOTOMY

isize	iside	fsize	fside	no	atr	abr	cptr	cpbr	fob	iso
4	1			1	4	0.5			2	2
4	1			1	6.5	4	28	20	2	2
4	1			1	10	1	28	10	2	2
4	1			1	6	1	14	10	2	2
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3	1			1	6	1	29	10	2	2
3	1	2	1	2	6	1	28	8	2	2
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4	1			1	6	1.5	20	16	2	2
4	1			1	8	2	30	15	1	2
4	1			1	6	2	12	30	2	2
4	1			1	8	2			2	2
4	1			1	6	2.5	70	80	2	2
3	1			1	4	2	22	24	2	2
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4	1			1	6	2			2	2
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4	1			1	6	1.5	19	7	2	2
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4	1	4	1	2	5	2.5	30	20	2	2
4	1			1	8	2	60	50	2	2
3	1			1	8	2	20	8	2	2
2	1			1	6	1	25	8	2	2
5	1			1	10	2	32	12	2	2
2	1	2	1	3	4	1.5	28	28	2	2
2	1			1	8	4	30	10	2	2
4	1	5	1	2	5	2	22	12	2	2
4	1	3	1	3	5	1	25	20	2	2

2	1			1	5	2.5	30	40	2	2
4	1			1	8	2	32	18	2	2
4	1			1	7	1	26	30	2	2
3	1			1	5	1.5	26	22	2	2
4	1			1	5	1.5	34	22	2	2
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4	1			1	5	2	44	20	2	2
4	1			1	5	2	26	42	2	2
2	1	1	1	2					2	2
3	1			1					2	2
4	1			1	6	1.5	40	10	2	2
5	1			1	4	2	25	20	2	2

comp1	comp2	comp3	comp4	comp5
1	1	1	1	
1	1	1	1	
1	1	1	1	CAME OUT IN RT LAT,UNABL TO VENTILATE RT LUNG
1	1	1	1	
1	1	1	1	
1	1	1	1	
2	1	1	1	37 F DLT TOO BIG
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	CXR SUBOPTIMAL
1	1	1	1	
1	1	1	1	
1	1	1	1	CXR DIFFICULT TO ASSESS
1	1	1	1	CXR COULD NOT ASSESS
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	2	1	35F;LIL BLD ON SCOPY,ALWAYS WRONG SIDE FOB CORR
1	1	1	1	
1	1	1	2	INITIALLY WRONG SIDE, LATER CORRECTED
1	1	1	1	INTRAOP LT UL NOT INFLATABLE, TUBE WITHDRAWN
1	1	1	1	
1	1	1	1	
2	1	1	1	FAILURE TO ADVANCE IN THE FIRST ATTEMPT
1	1	1	2	WRONG SIDE IN FIRST ATTEMPT
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	2	TWICE WRONG SIDE, PASSED OVER FOB TO LEFT SIDE

1	1	1	1	
1	1	1	1	BIG LEAK WITH 39F
2	1	1	2	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	
1	1	1	1	CXR ROTATED
2	1	1	2	35F PASSED WITH DIFFICULTY THRU CORDS,RT SIDE
1	1	1	1	
1	1	1	1	BRONCHIAL LUMEN HAD GONE INTO LL,PULLED OUT
1	1	1	1	

xrtr	cttr	ctlmb	ctrmb	dlttr	dltbr	dltht	dltused
20.1	20	13.1	13	5	5	4	4
20.8	18.9	12.07	12.8	5	4	4	4
19	17.1	11.6	12.9	5	3	4	4
16.9	16.5	13.1	14.9	4	5	5	4
15.1	15.5	10.2	11.6	3	2	4	4
19.1	17	11	10	5	3	3	3
15.7	15.2	9.1	11.7	3	1	2	2
18	15.5	12.1	13.7	5	4	2	3
16.7	17	11.5	12.5	4	3	2	2
18.9	17	11.7	12.2	5	3	5	4
17.8	16.5	10	14	4	2	2	2
19.9	19	12.1	14.5	5	4	5	4
19.1	19.2	12.5	14.05	5	4	4	4
16.4	19.6	13.5	13.4	4	5	4	4
	16.7	9.6	8.4		1	5	4
17.2	14.6	8.1	11.4	4	1	4	4
13.7	13.9	8.2	9.5	1	1	3	3
19.3	17.8	11.2	14.2	5	3	5	4
19.03	17.4	10	10.7	5	2	3	4
17.5	16.8	14.7	13.5	4	5	4	4
15.7	15.2	12.3	13.8	3	4	4	4
16	15.1	10.1	10.7	4	2	2	2
14	13.8	9.8	10.5	2	1	1	2
17.5	17.6	12.4	13.8	4	4	4	4
15.7	12	7.6	7.8	3	1	1	1
17	15.5	10.4	10	4	2	4	4
20.2	18.8	15.1	15.3	5	5	4	4
19.8	18.3	12.8	14.1	5	4	4	4
16.6	15.8	11.5	13.1	4	3	3	3
16.5	15	7.3	8.6	4	1	2	2
22	19.2	11.4	12.3	5	3	4	3
20.8	22	14.9	15.3	5	5	5	5
19.6	17.5	12.2	12	5	4	4	4
21.5	20.5	13.1	14.8	5	5	4	4
17.6	16.6	11.2	13.4	4	3	4	3
12.8	14	9	10.7	1	1	2	2
23.6	23	13.1	12.3	5	5	5	5
14.6	13.1	10.6	12	2	2	2	2
18.4	16.5	10	12.5	5	2	2	2
17.9	16.8	16.4	19.2	4	5	5	5
18.5	18	13.5	15.3	5	5	4	3

15.7	16.2	10.8	12	3	2	2	2
15.9	16.5	11.5	12.3	3	3	4	4
15.1	14.9	11.9	12.4	3	3	4	4
15.2	15.9	14.2	15.1	3	5	4	3
18.7	17.4	13.1	14	5	5	4	4
18.3	17.2	15.1	16.6	5	5	4	4
21	21.6	11.6	10.1	5	3	3	3
15.9	15.6	10.5	11.2	3	2	2	3
15.6	15.7	11.7	12.9	3	3	3	4
19.9	17.9	11.6	11.8	5	3	4	4
22.8	15.7	8.2	13	5	1	2	1
21.3	17.6	14	14.7	5	5	4	3
19.7	18.5	12.5	12.8	5	4	4	4
18.6	17.5	10.3	12.2	5	2	5	5

id	hno	hno1	sex	age	ht	wt	sur	isize
1	129290	F	1	32	166	52	RIGHT THO	4
2	200611	F	1	53	156	48	RIGHT WIN	4
3	208670	F	1	35	165	68	LEFT 7TH R	4
4	200959	F	1	47	171	55	RIGHT THO	4
5	71892	F	1	51	170	74	RIGHT UPP	4
6	210748	F	1	47	158	54	LEFT LOWE	3
7	213284	F	2	45	160	71	RIGHT LOW	3
8	192261	F	2	47	151	69	LEFT THOR	3
9	197355	F	2	38	145	44	RIGHT THO	2
10	155640	F	1	22	175	75	LEFT THOR	4
11	147507	F	2	54	148	52	WHOLE LU	2
12	741384	D	1	20	171	65	RIGHT PNE	4
13	195239	F	1	36	170	77	RIGHT PNE	4
14	207866	F	1	35	164	37	BULLECTO	4
15	148734	F	1	55	172	75	MCKEOWN	4
16	150738	F	1	54	163	62	MCKEOWN	4
17	221380	F	1	17	158	40	RIGHT DEC	3
18	182481	F	1	17	173	68	RIGHT DEC	4
19	169906	O	1	65	157	47	RIGHT DEC	4
20	156590	F	1	44	165	54	THORACOT	4
21	237994	F	1	62	163	56	RIGHT THO	4
22	235104	F	2	53	152	51	RIGHT THO	2
23	125208	F	2	40	151	69	RIGHT THO	2
24	244024	F	1	19	165	68	RT THORAC	4
25	250466	F	2	43	148	62	RIGHT THO	2
26	249680	F	1	65	163	83	RIGHT THO	4
27	225380	F	1	56	154	48	RIGHT THO	4
28	932281	D	1	55	160	55	THORACOT	4
29	175217	F	1	31	150	35	LEFT THOR	3
30	263164	F	2	42	153	60	RIGHT THO	2
31	232007	F	1	37	169	64	MCKEWON	3
32	289386	F	1	43	173	63	RIGHT THO	5
33	286150	F	1	39	155	63	RIGHT THO	4
34	230308	F	1	38	170	59	RIGHT UPP	4
35	223094	F	1	30	160	61	RIGHT THO	3
36	291344	F	2	24	155	39	RT THORAC	2
37	238709	F	1	41	180	75	RIGHT UPP	5
38	51905	F	2	45	158	56	RIGHT LOW	2
39	295513	F	2	38	145	48	LEFT THOR	2
40	302019	F	1	63	178	64	LEFT THOR	4
41	297942	F	1	41	160	48	RIGHT UPP	4
42	279114	F	2	30	156	52	THORACOS	2
43	284787	F	1	60	166	70	RIGHT THO	4

44	310049	F	1	18	160	45	RIGHT THO	4
45	289742	F	1	31	166	64	ANT MEDIA	3
46	245344	F	1	41	150	44	RIGHT WIN	4
47	542712	D	1	40	161	57	RIGHT THO	4
48	319409	F	1	45	152	44	RIGHT THO	3
49	225771	F	2	26	154	50	RIGHT MID	3
50	323018	F	1	30	154	46	RIGHT THO	4
51	282490	F	1	44	162	56	RIGHT THO	4
52	48358	F	2	52	153	42	LEFT LOWE	2
53	86036	F	1	33	168	56	LEFT LOWE	3
54	213244	F	1	59	158	61	RIGHT LOW	4
55	332144	F	1	26	175	58	RIGHT THO	5

iside	fsize	fside	no	atr	abr	cptr	cpbr	fob
1			1	4	0.5			2
1			1	6.5	4	28	20	2
1			1	10	1	28	10	2
1			1	6	1	14	10	2
1			1		1.5			2
1			1	6	1	29	10	2
1	2	1	2	6	1	28	8	2
1			1	6	0.5	25	9	2
1			1	8	0.5	25	9	2
1			1	4	1	20	4	2
1			1	6	1	28	8	2
1			1	6	1.5	20	16	2
1			1	8	2	30	15	1
1			1	6	2	12	30	2
1			1	8	2			2
1			1	6	2.5	70	80	2
1			1	4	2	22	24	2
1			1	5	1.5	22	17	2
1			1	7	2	2	2	2
1			1	6	2.5	19	20	2
1			1	5	1.5	22	5	2
1			1	5	1	28	12	2
1			1	6	2.5	30	35	2
1			1	6	2			2
1	1	1	5	4	2	40	30	2
1			1	6	1.5	19	7	2
1	4	1	3	7	2	26	26	2
1			1	5	2	20	4	2
1			1	5	1	24	11	2
1			1	5	1.5	46	11	2
1	3	1	3	8	2	28	26	2
1	5	1	2	5	1	12	6	2
1	4	1	2	5	2.5	30	20	2
1			1	8	2	60	50	2
1			1	8	2	20	8	2
1			1	6	1	25	8	2
1			1	10	2	32	12	2
1	2	1	3	4	1.5	28	28	2
1			1	8	4	30	10	2
1	5	1	2	5	2	22	12	2
1	3	1	3	5	1	25	20	2
1			1	5	2.5	30	40	2
1			1	8	2	32	18	2

1			1	7	1	26	30	2
1			1	5	1.5	26	22	2
1			1	5	1.5	34	22	2
1			1	6	2	45	60	2
1			1	5	1.5	20	30	2
1			1	5	2	37	22	2
1			1	5	2	44	20	2
1			1	5	2	26	42	2
1	1	1	2					2
1			1					2
1			1	6	1.5	40	10	2
1			1	4	2	25	20	2

iso	comp1	comp2	comp3	comp4	comp5	xrtr	cttr	ctlmb
2	1	1	1	1		20.1	20	13.1
2	1	1	1	1		20.8	18.9	12.07
2	1	1	1	1	CAME OUT	19	17.1	11.6
2	1	1	1	1		16.9	16.5	13.1
2	1	1	1	1		15.1	15.5	10.2
2	1	1	1	1		19.1	17	11
2	2	1	1	1	37 F DLT TC	15.7	15.2	9.1
2	1	1	1	1		18	15.5	12.1
2	1	1	1	1		16.7	17	11.5
2	1	1	1	1		18.9	17	11.7
2	1	1	1	1	CXR SUBOF	17.8	16.5	10
2	1	1	1	1		19.9	19	12.1
2	1	1	1	1		19.1	19.2	12.5
2	1	1	1	1	CXR DIFFIC	16.4	19.6	13.5
2	1	1	1	1	CXR COULD NOT ASSES		16.7	9.6
2	1	1	1	1		17.2	14.6	8.1
2	1	1	1	1		13.7	13.9	8.2
2	1	1	1	1		19.3	17.8	11.2
2	1	1	1	1		19.03	17.4	10
2	1	1	1	1		17.5	16.8	14.7
2	1	1	1	1		15.7	15.2	12.3
2	1	1	1	1		16	15.1	10.1
2	1	1	1	1		14	13.8	9.8
2	1	1	1	1		17.5	17.6	12.4
2	1	1	2	1	35F;LIL BLD	15.7	12	7.6
2	1	1	1	1		17	15.5	10.4
2	1	1	1	2	INITIALLY V	20.2	18.8	15.1
2	1	1	1	1	INTRAOP LT	19.8	18.3	12.8
2	1	1	1	1		16.6	15.8	11.5
2	1	1	1	1		16.5	15	7.3
2	2	1	1	1	FAILURE TC	22	19.2	11.4
2	1	1	1	2	WRONG SII	20.8	22	14.9
2	1	1	1	1		19.6	17.5	12.2
2	1	1	1	1		21.5	20.5	13.1
2	1	1	1	1		17.6	16.6	11.2
2	1	1	1	1		12.8	14	9
2	1	1	1	1		23.6	23	13.1
2	1	1	1	2	TWICE WR(	14.6	13.1	10.6
2	1	1	1	1		18.4	16.5	10
2	1	1	1	1	BIG LEAK W	17.9	16.8	16.4
2	2	1	1	2		18.5	18	13.5
2	1	1	1	1		15.7	16.2	10.8
2	1	1	1	1		15.9	16.5	11.5

2	1	1	1	1		15.1	14.9	11.9
2	1	1	1	1		15.2	15.9	14.2
2	1	1	1	1		18.7	17.4	13.1
2	1	1	1	1		18.3	17.2	15.1
2	1	1	1	1		21	21.6	11.6
2	1	1	1	1		15.9	15.6	10.5
2	1	1	1	1		15.6	15.7	11.7
2	1	1	1	1	CXR ROTAT	19.9	17.9	11.6
2	2	1	1	2	35F PASSEI	22.8	15.7	8.2
2	1	1	1	1		21.3	17.6	14
2	1	1	1	1	BRONCHIAI	19.7	18.5	12.5
2	1	1	1	1		18.6	17.5	10.3

ctrmb	dlttr	dltbr	dltht	dltused
13	5	5	4	4
12.8	5	4	4	4
12.9	5	3	4	4
14.9	4	5	5	4
11.6	3	2	4	4
10	5	3	3	3
11.7	3	1	2	2
13.7	5	4	2	3
12.5	4	3	2	2
12.2	5	3	5	4
14	4	2	2	2
14.5	5	4	5	4
14.05	5	4	4	4
13.4	4	5	4	4
8.4		1	5	4
11.4	4	1	4	4
9.5	1	1	3	3
14.2	5	3	5	4
10.7	5	2	3	4
13.5	4	5	4	4
13.8	3	4	4	4
10.7	4	2	2	2
10.5	2	1	1	2
13.8	4	4	4	4
7.8	3	1	1	1
10	4	2	4	4
15.3	5	5	4	4
14.1	5	4	4	4
13.1	4	3	3	3
8.6	4	1	2	2
12.3	5	3	4	3
15.3	5	5	5	5
12	5	4	4	4
14.8	5	5	4	4
13.4	4	3	4	3
10.7	1	1	2	2
12.3	5	5	5	5
12	2	2	2	2
12.5	5	2	2	2
19.2	4	5	5	5
15.3	5	5	4	3
12	3	2	2	2
12.3	3	3	4	4

12.4	3	3	4	4
15.1	3	5	4	3
14	5	5	4	4
16.6	5	5	4	4
10.1	5	3	3	3
11.2	3	2	2	3
12.9	3	3	3	4
11.8	5	3	4	4
13	5	1	2	1
14.7	5	5	4	3
12.8	5	4	4	4
12.2	5	2	5	5